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# ESSAYS IN THE ECONOMICS OF DEVELOPMENT AND ENVIRONMENT

*A Thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy in Economics*

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François Libois , le 7 février 2016

*"Il faut imaginer Sisyphe heureux."*

Albert Camus, *Le Mythe de Sisyphe*, 1942

*"Écouter la forêt qui pousse plutôt que l'arbre qui tombe."*

Friedrich Hegel

*"...je confesse facilement qu'il y a en la République des Utopiens bien des choses que je souhaiterais voir en nos villes de par-deçà, sans pourtant véritablement l'espérer"*

Thomas Moore, *Utopia*, 1516

# Contents

# Introduction

Une thèse est bien souvent écrite comme une suite d'idées qui s'enchaînent au fil des pages, se déroulent à la lecture et s'écoulent en lignes aussi précises que droites. La fluidité apparente n'est toutefois que l'artefact d'une présentation depuis un point de vue précis en fonction d'une conclusion choisie. Si l'on pouvait remonter le cours de la pensée, on passerait par de nombreux méandres, d'innombrables bras morts et quelques dérivations qui, parfois, au bout d'un long parcours souterrain, trouvent une résurgence et viennent alimenter la réflexion principale. Une thèse par articles perd en structure ce qu'elle gagne en richesse d'approches, de méthodes et de questionnements.

A la source fut le quatrième et dernier chapitre. Co-écrit avec Gani Aldashev, Joaquin Morales Belpaire et Astrid Similon, il fait suite à un travail de maîtrise entamé sous la direction de Jean-Philippe Platteau. L'article « Ecouraging private ownership of public goods » analyse sur le plan théorique et empirique l'effet sur le marché de la terre d'un mécanisme de subvention aux organisations non-gouvernementales (ONG) de conservation de la nature. Cette subvention permet aux bénéficiaires d'être remboursés de la moitié du prix d'achat des terrains convertis en réserves naturelles agréées. Nous montrons que l'introduction du subside accroît le prix des terrains à court terme, comme prédit par les théories les plus classiques. Par contre, sur le moyen terme, pour peu que les acquisitions permettent aux ONG de recruter de nouveaux bénévoles et que les objectifs de ces derniers soient identiques à ceux des anciens membres, le prix des terrains peut redescendre. Dans le cas d'étude analysé, il descend même progressivement à un niveau moyen proche de celui qui prévalait avant l'introduction de la mesure incitative. Cette diminution des prix ne peut s'observer que dans un contexte où les ONG ont une capacité à trouver des vendeurs qui valorisent l'intérêt général et à les convaincre de baisser leur prix pour contribuer à la fourniture de biens et services publics.

La problématique de la conservation de ressources naturelles renouvelables et épuisables est le pont qui lie le quatrième et le troisième chapitre. « Success and failure of communities » pose la question des conditions sous lesquelles une communauté, dont la capacité à surveiller et sanctionner ses membres est limitée, peut gérer l'accès à une ressource. La réponse est structurée autour d'un modèle théorique où les membres de la communauté fournissent un effort qui permet de récolter la ressource, mais aussi de s'en répartir les gains lorsque cette dernière est exploitée jusqu'à épuisement. La leçon principale de l'exercice théorique est qu'il n'est pas nécessairement plus simple pour une communauté de partager, sans effort excédentaire, la ressource à un moment donné du temps que de la conserver pour une exploitation future. Cela reste vrai même si la communauté ne peut qu'imparfaitement empêcher ses membres d'exploiter la ressource entre ces deux périodes et même si l'exploitation future ne peut être encadrée et donne lieu à une débauche d'efforts excédentaires pour s'approprier une ressource dont la valeur est devenue élevée.

La coécriture avec Jean-Marie Baland et Dilip Mookherkee de « Firewood collections, forest degradation and economic growth » a rythmé toute la thèse. Tel un fleuve qui s'épanche mais régulièrement revient vers son lit mineur, cet article a alimenté les autres chapitres et en a retiré des éléments nourriciers. C'est aussi l'article qui pousse le plus loin la mise en pratique des réflexions sur la conservation des ressources, et plus particulièrement de la ressource forestière dans l'Himalaya. Ce chapitre analyse les déterminants individuels de la collecte de bois de feu, évalue le lien entre ces collectes et la dégradation des forêts népalaises et mesure la réaction des ménages aux changements de leur environnement. La conclusion principale de l'article est que la croissance économique a un effet ambigu sur la consommation de bois de feu. Un revenu plus important pousse les ménages à collecter davantage de bois. Mais le développement économique coïncide également avec un changement de structure occupationnelle des ménages qui les amène à quitter l'agriculture. Or, au fur et à mesure que les ménages utilisent moins de terre, possèdent moins de têtes de bétail, s'éduquent plus et développent des activités non-agricoles, ils collectent moins de bois et utilisent plus de substituts. Au niveau des villages, des collectes agrégées plus importantes sont corrélées à une diminution de la couverture forestière. Or, un couvert forestier restreint augmente le temps de collecte de chaque unité de bois récoltée. Cette augmentation réduit elle-même les quantités de bois collectées. Les estimations présentées dans l'article montrent toutefois que l'effet retour sur les collectes est trop faible pour jouer un effet de stabilisateur automatique entre le niveau de collecte et l'étendue du couvert forestier.

Autour de la période étudiée dans le deuxième chapitre, le Népal endura onze années de guerre. ≪ Households in times of war ≫ analyse les stratégies d'adaptation des ménages pendant le conflit puis examine comment ces choix de court terme déterminent les trajectoires de reconstruction lorsqu'une paix relative s'installe. Les résultats principaux montrent qu'à court terme, le conflit réduit les inégalités de revenus entre les ménages de hautes castes et le reste de la population. Le revenu de tous les ménages baisse et celui des hautes castes diminue davantage encore dans les zones plus exposées au conflit. Les ménages de castes supérieures s'adaptent à la violence notamment en envoyant leurs jeunes hommes en dehors des zones de conflit. Les autres ménages investissent relativement plus de temps dans les activités agricoles, ce qui amortit la chute de leur revenu total. A moyen terme, cette stratégie perdure mais elle ne génère plus de revenus additionnels. Les castes supérieures peuvent, quant à elles, compter sur plus de ressources par individu et leurs sources de revenus sont plus diversifiées, notamment grâce à la migration. Si les inégalités entre castes sont réduites à court terme, elle se creusent à nouveau à moyen terme. La violence en elle-même n'est pas un gage de redistribution durable.

Il est important de noter que cette analyse se base sur les variations spatiales et temporelles de l'intensité du conflit au sein du Népal. Elle n'a donc point prétention à évaluer l'effet global du conflit, exercice ardu s'il en est puisque rien ne permet d'imaginer ce qu'il serait advenu du Népal en l'absence de guerre. Toutes les conclusions doivent donc se lire de manière relative, comme une comparaison de zones exposées plus ou moins fortement à la violence du conflit. Il est donc tout à fait possible qu'en sus et indépendamment des variations locales de l'intensité du conflit, la guerre ait facilité une redistribution du pouvoir politique, redistribution qui peut en elle-même modifier la société dans son ensemble. Mais des moyens aux fins, le chemin peut être long, sineux et parsemé d'embûches. Or, dans le contexte actuel, tant les analyses que les décisions politiques sont rares. Pour les citoyens, les incertitudes sont nombreuses et rendent ténus les espoirs de vie meilleure.

Au bout du chemin, il reste à dégager un fil. Trois chapitres analysent des institutions qui permettent de conserver des ressources naturelles. Le chapitre théorique et celui sur les ONG de conservation de la nature mettent plus l'accent sur l'aspect institutionnel. Le chapitre sur les collectes de bois de feu au Népal place davantage les institutions en filigrane pour mieux mettre en évidence les interactions entre les ménages et leur environnement.

Dans tout cela, le premier chapitre de cette thèse, le dernier chronologiquement parlant, semble bien isolé. Pourtant, il n'a pu atteindre sa profondeur qu'alimenté par les autres chapitres. Il est un peu comme un estuaire où l'on pourrait croire que l'eau du fleuve a disparu, masquée par le sel et les premières écumes de la marée. Pourtant, tous les éléments accumulés au fil du parcours sont bien présents. Des éléments méthodologiques. Des éléments de rigueur. Des éléments de contexte. Et même des éléments thématiques, comme le bois qui intervient comme resource que les bélligérants convoitent. Ces éléments sont réorganisés, dilués, mélangés à d'autres afin de leur donner une nouvelle ampleur et faire de ce premier chapitre un point d'entrée clé pour remonter le cours de la thèse.

# Chapter 1

# Households in Times of War: Adaptation strategies during the Nepal Civil War

**François Libois**

## Abstract [1]

This paper analyses short and medium term consequences of the Nepalese civil war on rural households livelihoods and on the inter-group distribution of income. Conclusions rely on two very rich datasets: the Nepal Living Standards Survey collected before, during and after the war and data on the number of killings by month and village during the eleven years of the conflict. Using the survey timing as a quasi-natural experiment, results indicate that in the short-run all households loose, but high castes by a larger extent. Short-term coping strategies determine medium term diverging recovery paths. Non-high castes allocate more labour in agriculture and loose more in the medium term. High castes diversify their income sources, notably by relying on migration, which allows them to recover.



*Keywords:*

Civil war ; Income distribution ; Labour ; Inequality ; Migration ; Nepal

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*There is no example of a nation that would have benefited from a long war.*

Sun Tzu, VI century BC, *The Art of War*

*The sharp reduction in income inequality that we observe in almost all the rich countries between 1914 and 1945 was due above all to the world wars and the violent economic and political shocks they entailed (especially for people with large fortunes). It had little to do with the tranquil process of intersectoral mobility described by Kuznets.*

Thomas Piketty, 2013, *Capital in the Twenty-First Century*

## 1.1 Introduction

One of the declared goals of Maoists in Nepal was to *"free the Nepalese society from feudalism and imperialism through the bourgeois democratic revolution"*[2]. Few years after peace agreements in 2006, can we see premises indicating that eleven years of war contributed to challenge historical inequalities? This study analyses the short and medium term effects of war on rural households livelihoods and disaggregates the consequences of the conflict between high castes and others.

This paper takes advantage of two very rich datasets to develop an original identification strategy of households' responses in times of war. Household level data were collected by the Central Bureau of Statistics of Nepal, in collaboration with the World Bank, before, during and after the war. The dataset has both repeated cross-sections and a rotating panel at the household level. The conflict dataset, collected by the Informal Sector Service Center (INSEC) of Nepal, gathered information on the number of casualties for each month and each of the 3,972 village development committees in Nepal during the eleven years of the civil war.

To identify short-term effects of the conflict, I use the second wave of data collection, which occurred during the conflict, as a quasi-natural experiment. Showing that the timing of the survey is orthogonal to the conflict, I compare villages within the same neighbourhood randomly surveyed at different points in time. The overall exposure to violence in a given area is not random. But, conditionally on the local exposure, whether an additional casualty occurred just before or just after the survey is random by the fact the order in which villages were surveyed is orthogonal to the conflict. In other words, the number of casualties before the survey, controlling for

2. Prachanda, Chairman of the Communist Party of Nepal - Maoist, A brief introduction to the policies of the CPN(Maoists). Source: *Maoist Information Bulletin*, No 8, 20 January, 2004

the total number of casualties around the survey, becomes a quasi-random variable and allows the estimation of causal effects.

I find that, in the short-term, violence reduces income and consumption for all rural households and especially more for high caste households. The analysis directly relates the reduction of income to a reduction of labour time in non-agricultural occupations. Non-high caste households mitigate the income loss by increasing their agricultural labour. For high castes, migration appears as a dominant strategy. A back of the envelope calculation allows estimating that the short-term effect of violence in 2003 has pushed 200,000 productive males of the high castes out of their households, which represents 4% of the high caste rural population.

The short-term adaptation pattern of households has lasting effects and has steered the recovery of high castes and others on different tracks. In the medium term, non-high castes households in conflict zones allocate relatively more labour to self-employed agricultural occupations, while high castes do not. Despite this divergence in terms of work time, both type of households experience a reduction of this income source. High castes mitigate this loss by a diversification of income sources and by the relative reduction of household size, two channels in which migration plays a key role. Consequently, even if high castes, who were specific targets of the Maoists, were losing more income in the short-term, they recovered in a seven years period including four years of peace are found to keep holding the upper hand.

I estimate the medium term effects on the last two waves of the panel. It allows focusing on the recovery path of households through the last years of the conflict and the first three to four years of peace as a function of conflict intensity between the two survey waves. The use of the household level panel already removes all time unvarying characteristics of households and villages which could be correlated with war and affect outcomes. Yet, conflict intensity might still be correlated with the change in income for instance. I therefore develop a two-step approach where I use the interaction between the price of wood and the distance to India as an exogenous predictor of the number of killings in surveyed villages. This predictor is strong from a statistical angle. It is relevant from an historical perspective because Maoists had financial needs, and timber smuggling to India was an important source of income. I also show that the exclusion restriction holds, given the large set of controls used and a series of exogeneity tests estimated using the pre-war wave of data collection.

This paper contributes to the literature in several dimensions. First, data are of high quality and were collected before, during and after the war at the household level. Considering the additional presence of a rotating panel, this is, in itself a rare strength. Second, the paper analyses household decisions in times of war and is immediately able to relate these choices to households' trajectories in post-war conditions. Third, the short-term methodology is creative. It actually builds on the work of Guidolin and La Ferrara (2007) and Lind et al. (2014) who rely on the timing of violent events to identify the effect of war. I somehow combine their approach with a strategy similar to Miguel and Kremer (2004). To identify treatment externalities of a deworming treatment on health and education outcomes they use experimental spatial variations in treatment intensity. The short-term methodology of this paper uses the survey as a quasi-natural experiment to identify effects of temporal variations of conflict intensity on household behaviour.

The current economic literature on the consequences of conflict is relatively scarce, by lack of data, and can grossly be divided in two parts, none of them directly addressing effects at the household level nor explicitly analysing inequalities between groups. Studies discussing effects on income mostly focus on mezzo or macro-economic outcomes and a significant share of the literature is based on cross-country studies (see Blattman and Miguel (2010) for a review and discussion) or on variations within countries and between sub-regions, like in Miguel and Roland (2011) analysis of post-war Vietnam or in Abadie and Gardeazabal (2003) analysis of the Basque country. There is an emerging and growing literature on micro-level consequences of conflict focusing on human capital accumulation through schooling [3], health [4] or social cohesion [5] and outcomes on the labour market [6]. Most of these papers identify a causal relationship using difference-in-differences between cohorts. This technique is however hard to apply at the household level and researchers who analyse production or consumption decisions often rely on extensive sets of controls [7] or exclusion restrictions [8]. As any study on a specific country, this paper does not address changes at

3. Chamarbagwala and Moran (2011); Shemyakina (2011)
4. Bundervoet et al. (2009); Minoiu and Shemyakina (2012); Valente (2015)
5. Bellows and Miguel (2009); La Mattina (2014)
6. Galdo (2013)
7. Kondylis (2010); Verpoorten (2009)
8. Miguel and Roland (2011)

the nationwide level since it would affect all households in the same way. The scope of the paper is not to address all consequences of the conflict on household lives. Yet, this research highlights that the redistributive effects of violence were anything but durable. The short-term adaptation strategies are key to understand what the postwar process has meant for rural households, what are some of the economic challenges they are confronted by. Last, the losers and winners of one day may actually change status once the war is over.

The paper is organized as follows. The next section presents the Nepali context. The third section describes data. Short-term effects of the conflict come in the fourth section and are followed by medium term effects in the fifth section, just before the conclusion.

## 1.2 Conflict in Nepal

In 1996, the "People's War" broke out in the Kingdom of Nepal, a landlocked country between India and China. The Communist Party of Nepal - Maoists (CPN-M) launched attacks against an agricultural bank and police posts in four of the 75 administrative districts of the country (Thapa, 2004, p.48). The conflict lasted for eleven years. At the signing of the peace agreement in June 2006, the death toll exceeded 13,000 casualties (INSEC, ears).

From a small scale and localized rebellion to a country wide war, the evolution of the conflict can very much be related to Maoists' military strategy [9]. At the beginning it was a small guerilla like organization. It benefited from the remoteness, the under-development and the lack of attention - if not the power *vaccum* - in a few isolated rural districts (Onesto, 2005, p.9-11). Following Mao's principles, Maoists first waged a mobile warfare, harassing police forces and building support in the countryside, mostly around their strongholds (Thapa, 2004, p.99).

The year 2001 is an important milestone in the civil war. The government created the Armed Police Force in January. In June, the King was murdered by his son. Two months later, a short cease-fire followed. In November, the Maoists broke it by launching a raid against the Royal Nepali Army (RNA), which got officially involved in the war thereafter. 2001 is the first year of the "strategic balance" phase of the

9. See Cowan (2013) and Mehta and Lawoti (2010) for a deeper discussion of Maoists' military strategy.

Maoists' plan. This year witnesses a clear extension and intensification of the conflict. The vast majority of killings occurred after this date.

In 2004, Maoists declared to control over 80% of rural Nepal (Onesto, 2005, p.227). They had established "People's Governments" in many localities. This year also corresponds to the "strategic offensive", the third phase of Maoists strategy. The People's Liberation Army (PLA) selectively targeted the RNA. At the nationwide level, the PLA was outnumbered by government forces (Onesto, 2005, p.220) and it had never been able to control any cities nor district headquarters. Conversely, the central government authority over the rural areas was very weak.

Waging a war requires resources. The CPN-M got little support from foreign countries (Ujpreti, 2010). 85% of arms and ammunition were looted during raids against police forces and, in a second stage, army bases (Mehta and Lawoti, 2010). Villagers had to offer food and shelter for Maoists fighters walking from one place to another. Sometimes villagers had also to provide free labour (Lecomte-Tilouine, 2013, p.234). On top of direct contributions in nature, the CPN-M levied taxes or resorted to extortions especially against villagers earning monetary income through labour, pensions or remittances (Lawoti, 2010, p.23). Cailmail (2013, p.157) quotes a former Gorkha soldier in the Indian Army stating:

> Life is hard, for the Maoists regularly come here asking for food and money. (...) If I do not abide by their rules, they threaten me. Five months ago, they kidnapped my son to force me to give them money. They still come every month, when I get my pension, and ask me for money, food and lodgings.... The Maoists see only my income and not all the expenses I have.

While this example is extreme, contributions were generalized (Ghimire, 2013; Lecomte-Tilouine, 2013; Lama Tamang et al., 2006). Another source of income was the partial to full control of forest products trade. Lekhraj Bhatta, Head of Seti-Mahakali People's Government, explains that *"the resources for running our government come from taxes on the natural resources available in our region (such as herbs and timber), trade duties and voluntary contributions from various professionals and the ordinary working population"* (ICG, 2005).

Means have ends. The CPN-M increased their control of the countryside to put pressure on cities and change the development path of Nepal (Onesto, 2005, p.13). In the 40 demands presented just before the onset of the conflict, 17 items deal with democratic reforms asking for more equality and 14 with livelihoods improvements (Bhattarai, 1996). The location of casualties reflects this last point. Poverty (Do and Iyer, 2010; Hatlebakk, 2010), inequalities and ethnic fractionalisation (Nepal et al., 2011) and land concentration (Hatlebakk, 2010) were fertile grounds for fighting and recruitment (Macours, 2011).

Ethnicity is neither the official motto of the conflict nor its sole driver [10]. However, there is a strong correlation between long standing economic and political exclusion and the membership to some ethnic groups of the Hills and Mountains - like Magars and Gurungs - or other clearly identified population subgroups such as Dalits.

The Maoists were keen on targeting high caste members and especially Bahuns and Chhetris. Nevertheless, the civil war had deep consequences on all villagers' livelihoods. The effect on schooling attainment is debated among economists (Valente, 2014; Pivovarova and Swee, 2015). Regarding gender consequences, Valente (2015, 2011) finds that the sex ratio at birth is distorted against men and that women marry earlier. Women would also work more (Menon and Rodgers, 2013).

The anthropological literature reports much broader consequences on the life of villagers. Migration, especially of young males was massive. Every young men was a potential warrior for the Maoists and was therefore a potential recruit. Ghimire (2013, p125) observes *"voluntary exile in practically every family"*. Mobility of staying villagers was severely restricted. Access to cities was difficult and trade activities were disrupted (Lama Tamang et al., 2006). Even activities around the village, like forest products collection, were getting harder. Maoists repressed formal and informal lenders, "feudals" and "exploiters" (Shrestha-Schipper, 2013, p.272). On the other side, Maoists claimed to provide public goods, increase teacher assiduity, empower women and dalits, reduce alcohol consumption, .... (Lawoti, 2010; Lecomte-Tilouine, 2013, p.252). Ghimire (2013, p.128) reports that Maoists fighters spent also time to help villagers in their everyday life with the aim of building support for the rebellion.

10. For a longer perspective on the political economy of the Nepalese conflict, see inter alia Sharma (2006).

The mode of action and the strategy of the Maoists has therefore deep consequences on the distribution of power and income, especially in rural areas where the conflict was concentrated. The goal of Maoists was not to crush the rural economy since rural support was important for them both for political and economic reasons (ICG, 2005). Hence, this paper focuses both on the average effect of violence and on the differential consequences of violence on particular population subgroups.

## 1.3 Data

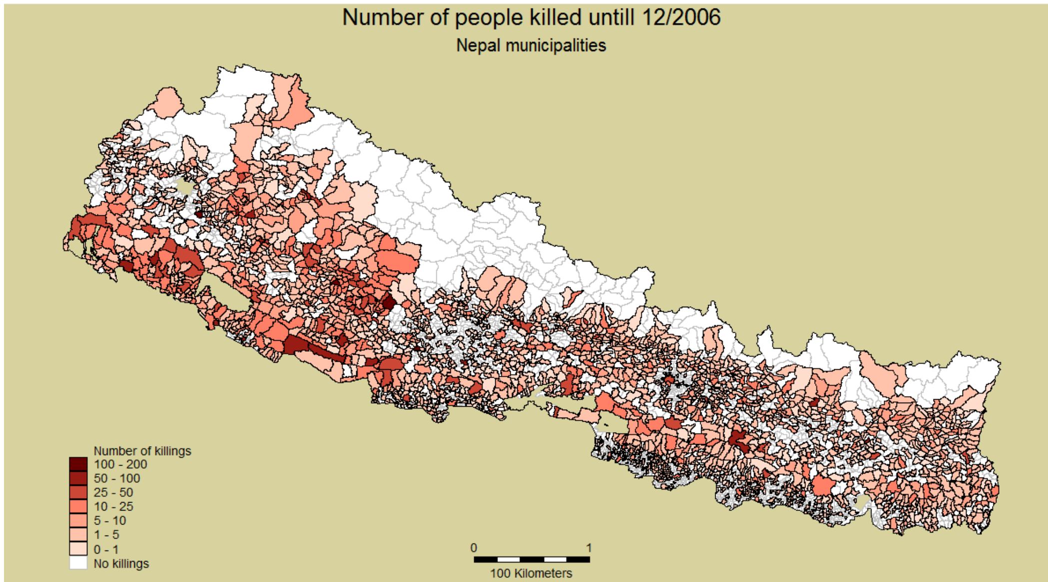
Compared to the usual scarcity of microlevel data in times of war, Nepal stands up as a fertile ground for quantitative work on the consequences of conflict. On the one hand, the civil war in Nepal is well documented. On the other, household level data were collected even during hostilities. In this section, I first describe data on conflict intensity, then household level data and discuss how both sets overlap. The final subsection quickly introduces secondary sources of information used as controls.

### 1.3.1 Conflict data

The Informal Sector Service Centre (INSEC), a very active Nepali human rights organization, collected extensive data on conflict intensity and human rights violations during the whole duration of the conflict. The INSEC database (INSEC, 2009) is considered the most reliable data source on conflict intensity during the Maoist insurgency. This database is used in many papers dealing with the conflict including Nepal et al. (2011) and Valente (2014). INSEC had a broad grassroots network of local contacts in the 3972 Village Development Committees (VDCs) and municipalities of Nepal. For each and every VDCs, INSEC reports the number of conflict related casualties by warring parties and by months during the eleven years of the conflict. Of the 13,236 casualties reported by INSEC, I use 12,957 of them which are time and geo-localized. The remaining 2% do not have a precise location or month and are therefore omitted in the analysis.

Casualties are widely spread over the entire country. By the end of 2006, 40.7% of Nepali VDCs experienced at least one conflict related killing within their perimeter. Figure 1.1 shows the geographical extent of the conflict at the end of the war. The

Figure 1.1 – Spatial distribution of killings during the People's War



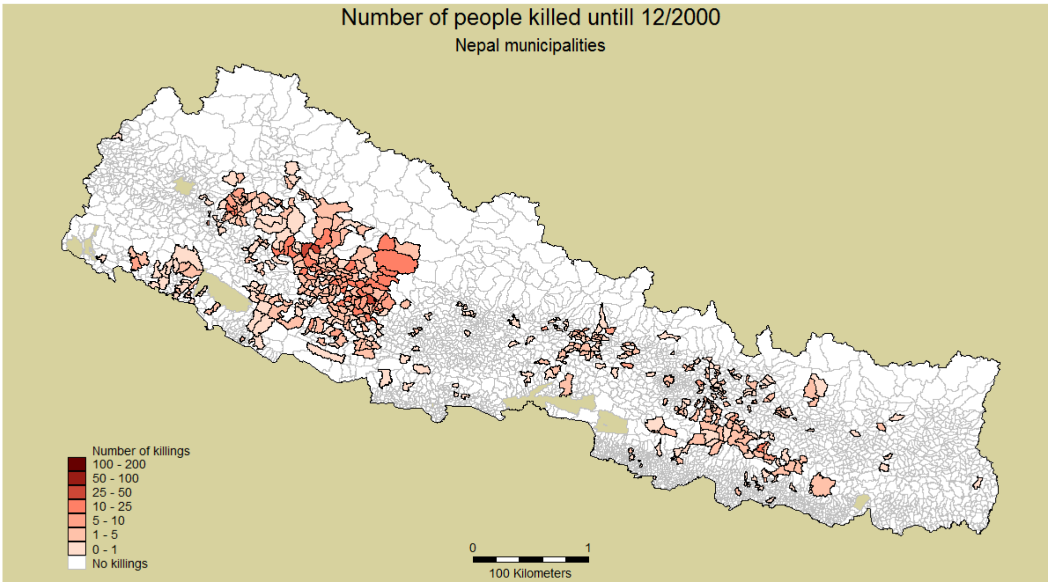

darker a VDC on the map, the larger the number of killings during the conflict [11]. All regions of Nepal were directly affected by the conflict, however at varying degree [12] and varying timing. Over the eleven years of the conflict, there is a clear intensification in the 2000's. As shown in figure 1.2, hostilities till 2001 were mainly concentrated around the Rolpa and Rukum district in the West, and at the East of Kathmandu. The creation of the Armed Police Force, the attack of army barracks by the Maoists and the subsequent implication of the Royal Nepal Army corresponds to a clear escalation of the conflict, both in terms of intensity and extension.

### 1.3.2 Household data

The Central Bureau of Statistics of Nepal (CBS) in collaboration with the World Bank gathered the Nepal Living Standards Surveys (NLSS). It is a nationally representative survey conducted in 1995/96, 2003/04 and 2010/11 [13]. The surveys follow the World Bank's Living Standards Measurement Survey (LSMS) methodology and

11. Transparent areas within Nepal correspond to national parks
12. The apparent peace in the North is just related to the low attractiveness, the remoteness and the underpopulation of the Himalayan high mountains
13. I further refer to the 3 waves as 1995, 2003 and 2010 since, for each wave, 75% of data collection occurred in the first of the two years.

Figure 1.2 – Spatial distribution of killings till December 2000




compile household and village level data. I use household level data in rural areas which cover a wide range of topics: demography, production decisions, consumption choices, income level and sources, health, education, etc.

The structure of the dataset is rich, with both repeated cross-sections and a rotating panel. Households in the cross-sections were always selected in a two-stage sampling process, with a sampling of wards [14] followed by a sampling of households within the ward. Since we focus on the effect of the conflict in rural areas, we are left with a sample of 2,657, 2,748 and 3,900 rural households living in 215, 229 and 325 wards respectively in 1995, 2003 and 2010. In 2003, the CBS tracked previously surveyed households in 75 randomly sampled rural wards of the first wave. Enumerators could find back almost 800 households. In 2010, the CBS tracked households in 35 of these 75 wards and in 40 of the 229 rural wards of the second cross-section. The sampling of wards was again random. On top of the three repeated cross-section, we have a rotating panel with 368 households surveyed three times, 424 households surveyed both in 1995 and 2003 and 434 surveyed in 2003 and 2010 [15].

14. A rural ward roughly corresponds to a hamlet and is the smallest administrative unit in Nepal. In practice, the rural sample has at most one ward per VDC.

15. Additional details on sampling methodologies are available in CBS (2009), CBS (2004) and CBS (2011).

### 1.3.3 Household and conflict data

The existence of pre, contemporaneous and post-conflict household level data already is a major boon. Their combination with precise information on insecurity levels is a clear advance with respect to the quantitative literature on conflict. It avoids many drawbacks arising when recall data are used, both with respect to household behaviour and to conflict shocks. I also work at a very disaggregated level. It means that causes and consequences can be related with little aggregation bias and measurement errors, which often are at risk in the analysis of conflicts.

Figure 1.3 illustrates the partial temporal overlap between household surveys and the Nepal civil war. The solid red line displays the number of people killed by month between 1996 and 2006. Bars and the associated right scale stand for the number of cross-sectional wards surveyed in each month. The first wave of data collection started clearly before the onset of the conflict. The second wave of data collection lasted for one year and occurred shortly after the first intense period of the conflict and at the beginning of the second intense phase. The last wave of data collection happened in 2010, way after the end of the conflict.

For the short-term analysis, I focus on the second wave of the NLSS. Data collection started in April 2003 and ended up in April 2004. If the enumeration started during a cease-fire as underlined by the drop in the number of casualties at the beginning of 2003, a new violence episode broke out in September and the remaining data collection continued in times of war. Figure 1.4 illustrates the coverage of the 2003 survey and the spatial dispersion of the conflict [16]. The blue dots indicate that a village has been enumerated as part of the second cross-section. The darker red is a village, the higher the number of conflict related killings during the 13 months of the survey. CBS (2004) reports that interviewing households in conflict affected areas was challenging. They however managed to do it, but for eight cross-sectional and four panel wards. Only eight wards of the 229 could not be surveyed as scheduled initially. For the panel, six of the 75 wards were visited during a second attempt. Considering that 2,678 people got killed during this period, the timely enumeration rate can be considered as a great record. Data quality is further discussed in the short-term identification strategy section.

16. In the appendix, figures 1.10,1.11,1.12 and 1.13 provide the spatial dispersion of killings and the coverage of the survey by quarter

Figure 1.3 – Number of people killed and of wards surveyed by month

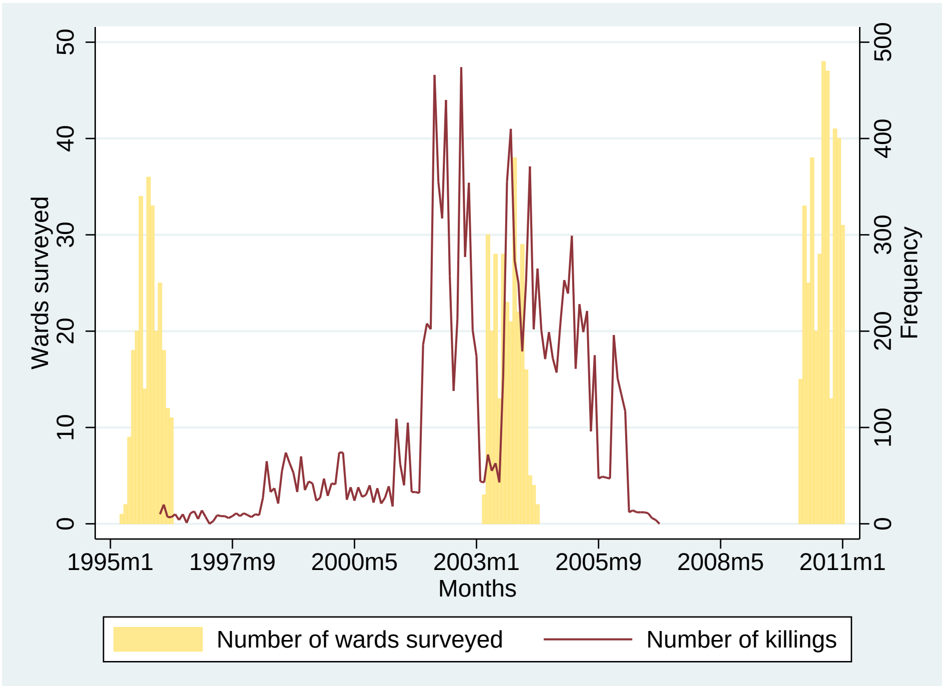
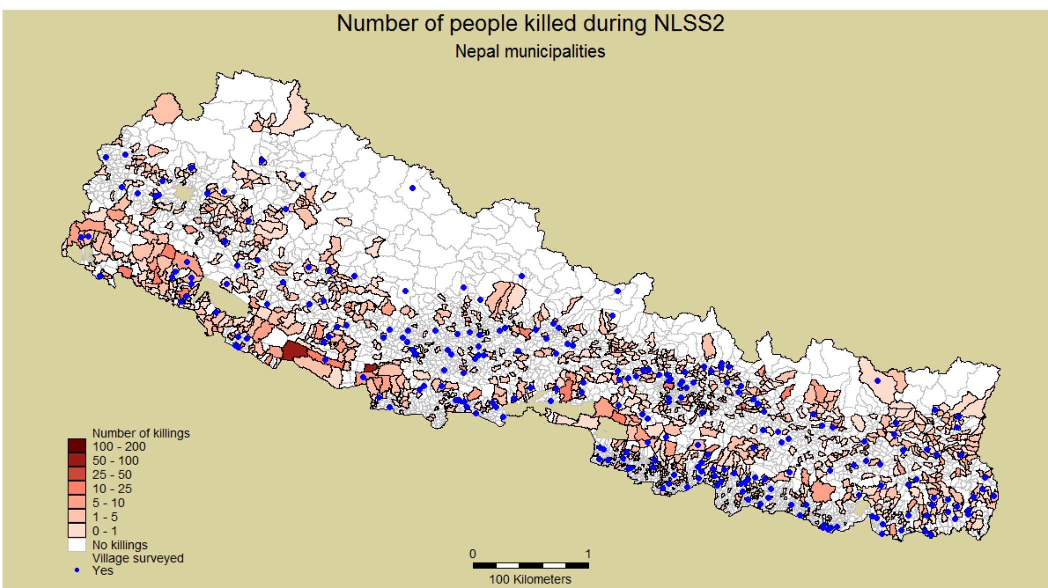



Figure 1.4 – Spatial distribution of killings during NLSS2 and coverage of the survey



The longer term analysis also rely on pre- and post-conflict data. Pre-conflict data picture livelihoods baseline levels unaffected by the conflict's extent and sequence. Post-conflict data incorporate the overall effect of the conflict on all Nepali households, and also the heterogeneous consequences of varying conflict intensities over time and space.

In this context and despite a smaller sample size, the household panel sharpens the understanding of potentially remaining estimation bias. I use the panel to estimate the medium term effects of war while controlling for unobserved time invariant characteristics at the household level. I test whether conflict related attrition is important too. In this sense, the panel is used to shed light on potential biases related to household selection in cross-sections.

### 1.3.4 Additional sources of data

The unit value price of timber imports in India comes from the International Tropical Timber Organization (ITTO). In yearly reports (ITTO, ears) and in its Annual Review Statistics database (ITTO, 2013), ITTO monitors the trade of primary wood products. More specifically, I use data on the yearly average import prices (in USD per cubic meter) of industrial round wood in India. Prices are differentiated for coniferous trees, non-coniferous tropical trees and non-coniferous non-tropical trees. The price is adjusted for the VDC biome data (MENRIS-ICIMOD, 2008). Figure 1.14 in the appendix shows the evolution of these three timber prices between 1996 and 2010.

The subsequent analysis also relies on satellite images from two different sources to measure environmental and climatic conditions at the VDC level. The Tropical Rainfall Measurement Mission (TRMM) provides monthly rainfall estimates at 0.25 degree grid square[17]. The TRMM is a joint project between the NASA and the Japanese Aerospace Exploration Agency which has been launched in 1997 to study tropical rainfalls. Various technological innovations (including a precipitation radar, flying for the first time on an earth orbiting satellite) and the low flying altitude of the satellite increase the accuracy of climatic measures. It is therefore well adapted to the Nepalese context. Interestingly enough, the TRMM products combine satellite measures with a regular calibration using monthly terrestrial rain gauge data. These

17. It roughly corresponds to 27 km in Nepal.

are currently some of the most accurate measures of precipitations. Together with Baland et al. (2015) and Fetzer (2014), this paper is the first one to use these data in the economics literature, and the first to use them for Nepal.

I also use a VDC level Normalized Difference Vegetation Index (NDVI) to capture the greenness of a VDC in a given year. Using the MODIS sensor, NASA and Carroll et al. (2011) provide a bimonthly measure of the NDVI at a 250m resolution. The NDVI is defined as the ratio $\frac{\text{Near Infra Red - Visible Red}}{\text{Near Infra Red + Visible Red}}$. It proxies the amount of radiation captured by chloroplasts, which are green because they absorb all visible colours but green. The closer to one the ratio is, the denser is the vegetation cover of the pixel. In this project, and consistently with the bimonthly measure, I average, for each VDC, the yearly maximum of each VDC's pixel [18]. This variable intends to capture the peak biomass potential over the last 12 months in the VDC. It can be used as a VDC level control of the renewable natural resource productivity, including potential agricultural production.

## 1.4 Short-term effect of the conflict on households' choices

This section aims at estimating households short-term responses to violence episodes in their immediate neighbourhoods. I first discuss the econometric strategy before exposing results.

### 1.4.1 Identification strategy: the survey as a quasi-experiment

#### common wisdom approach

A naive approach to estimate the short-term effects of a conflict on a variable $y$, say income, can be written as:

$$y_{im} = \gamma_0 + \gamma_1 K_{\kappa vm}^{[m-z;m-1]} + \epsilon_{im} \tag{1.1}$$

where outcome $y$ of household $i$ in month of survey $m$ is a function of the number of killings $K$ in the last $z$ months in the $\kappa$ kilometres around its village $v$. $\gamma_1$ is the average variation of $y$ related to one more killing in the $z$ months before the survey. $\epsilon$ is an idiosyncratic term.

18. The observed maximum over the period is already what is done over the 16 days period of production. It reduces measurement errors related to cloud cover.

This approach might be misleading because of reverse causality or omitted variable bias. If belligerents target wealthier households, because the Maoists want to free Nepal from feudalism or because the Government overprotects richer households, then the estimation of $\gamma_1$ will be upward biased. If Maoists recruitment is easier in poorer areas or if poverty is correlated to remoteness, while remoteness eases up the insurgency, then we expect the estimation of $\gamma_1$ to be downward biased.

It is therefore crucial to compare comparable households facing different conflict intensities. This is straightforward in a thought experiment where citizens would be randomly killed across the country. In such a case, a difference in means would suffice and the equation (1.1) would be the right model. This thought experiment is however not feasible nor desirable in the real world. Hence, I propose to use the timing of the survey as a source of exogenous variation in conflict exposure.

**Intuitive approach**

Intuitively, consider four villages, $A$, $B$, $C$, and $D$. By design of the survey, let's assume that households in the first two villages are enumerated in May and in July for the last two. This sequence has been arbitrarily determined before the survey starts. Let's further assume that someone got killed in June close to villages $A$ and $C$, far away from villages $B$ and $D$. Then, the following model could be estimated:

$$y_{im} = \alpha_0 + \alpha_1 K_{\kappa vm}^{[m-z;m-1]} + \alpha_2 K_{\kappa vm}^{[m-z;m+z-1]} + \alpha_3 \text{July}_m + \eta_{im} \tag{1.2}$$

In this intuitive model with four villages and one casualty, the dependent variable $y$ is a function of the number of conflict related killings $K$. The first variable, $K_{\kappa vm}^{[m-z;m-1]}$, captures the number of killings in the $z$ months before enumeration in the $\kappa$ kilometres around the village $v$. It is equal to one only for households living in village $C$, enumerated in July. The second variable, $K^{[m-z;m+z-1]}$ is the number of killings around the enumeration month. It is equal to one for villages $A$ and $C$ and zero for the two others. In terms of interpretation, the parameter $\alpha_1$ captures the differential effect in $y$ of being exposed to one more casualty just before the survey, compared to experience it just after. By design of the survey, $A$ and $C$ are statistically similar sampling units. They face the same potential violence around the survey date, but at the time of enumeration, only inhabitants of village $C$ had a direct experience of violence in their neighbourhood. Of course, villages $A$ and

$C$ are systematically different from the two others because they were potentially affected by the same strictly positive level of violence. This systematic difference is captured by $\alpha_2$, the parameter associated with the level of violence around the survey. The parameter $\alpha_2$ captures the correlates of household exposure to current conflict conditions. It includes adaptation to anticipated levels of violence in the $\kappa$ kilometres around the village as well as short-term general strategies of the belligerents. The specification (1.2) also incorporates a month fixed effect to partial out the estimation of $\alpha_1$ from seasonal fluctuations.

This econometric strategy is close to Miguel and Kremer (2004) when they identify the treatment externalities of a deworming treatment on education and health outcomes of students. In their main specification, they control for the total number of schools in a given area, a potentially endogenous variable, to infer the effect of the treatment by estimating the parameter associated with the total number of treated schools in this area. In this paper, I control for the total number of killings in a given area over a arbitrary period of time, and the key orthogonal variation comes from the predetermined random timing of the survey and not from the random treatment assignment over space.

**Econometric specification**

The model presented in (1.2) can be extended for a continuous measure of conflict intensity and additional controls. Econometrically, the short-term estimation strategy is written as

$$y_{im} = \beta_1 K_{\kappa vm}^{[m-z;m-1]} + \beta_2 K_{\kappa vm}^{[m-z;m+z-1]} + \beta_3 K_{\kappa vt}^{[onset;m-z-1]} + \mathbf{X_{im}} \mathbf{\Phi} + \lambda_l + \mu_m + \varepsilon_{im} \quad (1.3)$$

in which the outcome variable $y$, say income, is a function of the killings in the last $z$ months, $K^{[m-z;m-1]}$, controlling for the number of killings in the $z$ months before and after, $K^{[m-z;m+z-1]}$. Additional controls include the number of killings from the onset of the conflict till $z-1$ months before the survey, $K^{[onset;m-z-1]}$, a vector of control variables $\mathbf{X}$ as well as spatial and temporal fixed-effects. $\varepsilon$ is a idiosyncratic component.

The causal interpretation of $\beta_1$ relies on several assumptions. First, conditionally on controls, the timing of enumeration has to be orthogonal to the conflict expansion.

Second, the correlation between killings before and after the enumeration should be relatively small to allow the estimation of $\beta_1$. Third, the quality of the survey has to be independent to the conflict. Fourth, the pool of households enumerated in a given village should not be affected by the conflict. Fifth, households should not perfectly anticipate violence. Sixth, villages experiencing similar level of violence around the survey should follow a parallel trend. Under these assumptions, the coefficient of interest $\beta_1$ captures the differential effect of experiencing one additional casualty before the survey compared to have it just after.

**Important assumptions: discussion**

The short-term identification strategy of this paper relies on the randomness of the enumeration timing so as to create a quasi-natural experiment. Due to the extent of the survey, the 229 wards could not be surveyed at the same point in time. 13 months were necessary to enumerate the 2,748 households of the second cross-section. To guarantee a representativeness of seasons, the CBS surveyed different wards in different months within the same region. On top of the qualitative information reported in the data section which support the claim that primary sampling units could be enumerated as planned, I can build a test of orthogonality between the survey process and the conflict expansion. Knowing the spatial and temporal distribution of killings during the whole duration of the survey I can try to predict the enumeration of a ward using violence over the last months. Based on equation (1.3), the following equation formally tests the quasi-randomness assumption:

$$surv_{vm} = \beta_1 K_{\kappa vm}^{[m-z;m-1]} + \beta_2 K_{\kappa vm}^{[m-z;m+z-1]} + \beta_3 K_{\kappa vt}^{[onset;m-z-1]} + \mathbf{X_{im}\Phi} + \lambda_l + \mu_m + \varepsilon_{im} \tag{1.4}$$

where the dependent variable is a dummy variable indicating if the sampled village $v$ got surveyed in month $m$. Estimation of equation (1.4) is restricted to the set of villages surveyed and to the duration of the survey. Table 1.1 reports estimations of equation (1.4) by a linear probability model for a distance of 20km. The coefficient of the number of killings 3, 6 or 9 month before is never statistically significant, with or without controls for environmental conditions, such as NDVI or rainfall z-scores (even columns). Correcting standard errors for spatial auto-correlation using Conley

(1999) does not affect the conclusions[19]. In the appendix, figure 1.15 reports the average effect of the conflict on the probability to enumerate households in a VDC in a given month, using month windows ranging from one to twelve months. The four graphs, from top to bottom and left to right, respectively correspond to casualties within, in the 10km, 20km and 40km around the village. All coefficients plotted in this figure are estimated following equation (1.4) with an empty **X** vector. It confirms that, conditionally on fixed-effects, the enumeration timing is statistically orthogonal to the conflict expansion.

Table 1.1 – Linear probability model of a sampled village enumeration month

| | (1)<br>3 months | (2)<br>3 months | (3)<br>6 months | (4)<br>6 months | (5)<br>9 months | (6)<br>9 months |
|---|---|---|---|---|---|---|
| $Killings_{20km}^{[m-z;m-1]}$ | -0.0005 | -0.0005 | -0.0002 | -0.0002 | -0.0003 | -0.0003 |
| | [-0.46] | [-0.45] | [-0.38] | [-0.36] | [-0.84] | [-0.85] |
| $Killings_{20km}^{[m-z;m-1+z]}$ | 0.0002 | 0.0002 | 0.0002 | 0.0002 | 0.0001 | 0.0001 |
| | [0.32] | [0.32] | [0.62] | [0.62] | [0.53] | [0.53] |
| $Killings_{20km}^{[onset;m-z-1]}$ | -0.0000 | -0.0000 | -0.0000 | -0.0000 | 0.0000 | 0.0000 |
| | [-0.12] | [-0.20] | [-0.57] | [-0.66] | [0.51] | [0.46] |
| Belt-Zone F.E. | Yes | Yes | Yes | Yes | Yes | Yes |
| Month F.E. | Yes | Yes | Yes | Yes | Yes | Yes |
| Environment controls | No | Yes | No | Yes | No | Yes |
| Observations | 2977 | 2977 | 2977 | 2977 | 2977 | 2977 |

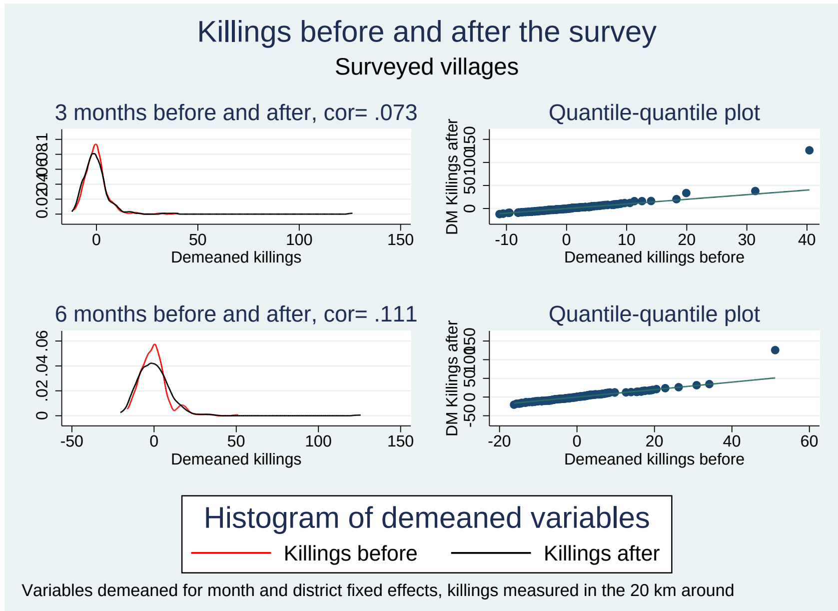
Standard errors clustered at the VDC level, $t$-statistics in brackets $^{*}p < 0.1$,$^{**}$ $p < 0.05$,$^{***}$ $p < 0.01$

The weak correlation between killings before the survey and after is a more technical requirement. The survey could well be orthogonal to the conflict, but if the conflict intensity does not vary at all over time, the variance of the estimator of $\beta_1$ would be infinitely large. Figure 1.5 reports the correlation between demeaned killings before and after enumeration[20]. This correlation is equal to 0.073 in the three months window and to 0.11 in the six months window. The inflation of the variance due to collinearity thus remains moderate.

Figure 1.5 also shows that the distribution of killings in the 20km around the village is very similar before and after the survey, using a three or a six months

19. The correction is performed following Hsiang (2010), tables available upon request.
20. "Demeaned" stands for the fact that killings are partialled-out from month and belt-zone fixed effects.

Figure 1.5 – Distribution of demeaned killings before and after the survey month in each village, NLSS2




window. The left column reports kernel densities of both distributions for the 229 villages of the second cross-section. Distributions overlap nicely, both if we consider killings three months (top row) or six months (bottom row) around the survey. The overlap is even more striking in the right column which displays the corresponding quantile-quantile plots allowing a finer comparison of the two distributions. The small discrepancy between the two distributions only comes from the distribution's tails. The similarity between distributions is consistent with a quasi-randomness of the enumeration timing, conditionally on temporal and spatial fixed-effects.

A threat to identification strategy could arise from variations in the quality of data. Hatlebakk (2007) shows that this should not be a worry. Enumerators did not spend a different amount of days in areas controlled by the Maoists. Response rates are very similar. Standardized answers like 0 and 5 are not more frequent. There is no evidence of Maoists influence on critical questions like the minimal daily wage. Standard deviations of critical variables are stable. The author concludes that the quality of data in 2003 is not different from data collected in 1995, before the conflict.

Another concern is representativeness of the cross-section collected during the war. Data correctly reflect rural Nepal only if households' conflict related migration is limited. While I cannot explicitly measure migration, I use the panel to show that conflict related attrition of households was not large. This indirectly shows that households, as a whole, did not migrate more in conflict zones. For individuals, variations in households size provide a more precise, however implicit, measure of migration. This is widely discussed, among other results, in the next subsections.

The relevance of the method also hinges on limited households' anticipations of conflict intensity. If households anticipate perfectly the conflict intensity, then, there should not be any differences between experiencing killings just before or just after enumeration. In such conditions, $\beta_1$ should not be different from 0. Under imperfect anticipations, the effect of conflict intensity on household choices therefore tend to be underestimated.

The last and crucial assumption is that villages facing similar level of violence actually follow a parallel trend. This assumption is first weakened by the presence of a large set of controls in equation (1.3). $\beta_3$ captures the correlates of household exposure to historical levels of violence. It is potentially affected by the Maoists long term strategy and by Governmental responses. Month specific parameters $\mu$ control both for the general rise in violence during the survey due to the end of the cease-fire and for seasonal effects. 33 belt-zone specific parameters $\lambda$ restrict the estimation of the coefficient of interest to villages in comparable areas. Belt-zones are defined as the interaction between ecological regions and administrative areas. Mountains, Hills and Terai form the three main ecological regions of Nepal and are located along a North-South gradient. The 14 administrative zones are organized on a West-East gradient [21]. Hence, the interaction captures systematic differences in ecological conditions and long-term development which are highly correlated with the distance to Kathmandu. $\mathbf{X}$ is a vector of control variables including rainfall anomalies (z-scores) and greeness of vegetation (NDVI) of the village associated with a vector of parameters $\Phi$. It is important to control for rainfall and biomass potential since micro-spatial variation of ecological conditions could determine both the level of violence in a specific area and outcome variables of rural households.

As in any study relying on parallel trend assumptions, controls, despite their number, might still be insufficient to guarantee the parallel trend assumption. This

21. See figure 1.9 in appendix for a map of belts and zones.

study is partly an exception. Indeed, the fact that village $A$ was surveyed before $C$ is purely random. The two villages are *ex-ante* statistically similar and, by the law of large numbers, have on average, the same trend. On top of that, trends are short since we mostly focus on the 6 months before and after the survey. This further strengthens the credibility of the parallel trend assumption.

### 1.4.2 Results

The short-term analysis relies on the cross-sectional regression presented in equation (1.3). Each household $i$ is observed once, in month $m$. The dependent variables are different outcomes important to understand household livelihoods in war times. The next tables report estimations for $z = 6$ and $\kappa = 20$, i.e. I report the effect of violence in the last six months and in the 20 kilometres around the village. This specific choice is arbitrary, clarifies the exposure, is discussed later on and does not affect conclusions. For each dependent variable, results appear first without additional controls and second with controls for rain deviations and greenness in the last twelve months. Both estimations include months and belt-zone fixed effects.

This subsection is organized in three parts. I start with short-term effects on the whole rural population, continue with heterogeneous responses for high castes versus non-high castes and finally discuss mechanisms behind and robustness of the results. In terms of themes, I first consider the short-run impact of conflict on changes in household income and decompose it by sources. This raises the question of labour allocation and production decisions. I then analyse how it translates into consumption choices. The main insight is the drop of income for all households, but especially more for high castes, the additional working time of non-high castes in agriculture and the fact that high castes resort to migration.

#### Short-term effect of the conflict

Additional killings have large and statistically negative effects on total household annual income. Estimation (2) in table 1.2 shows a drop of annual income by 1,257NPR$_{2010}$ when one additional person got killed in the 20km around the village during the six months before the survey, compared to having this person killed in the six months just after the survey [22]. The average short-term effect of increased violence before the survey is equal to -15,164NPR. It represents a sizeable drop by 15% with respect to the average annual household income of 104,727NPR, reported in the penultimate line of the table. This conclusion is robust to controlling for environmental conditions, like rain and greenness of the area.

Table 1.2 – Income in war times in ($NPR_{2010}$)

| | Total income | | Agri. labour inc. | | Non-Agri. labour inc. | | Transfers | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $Killings_{20km}^{[t-6;t-1]}$ | -1265.4*** | -1256.8*** | 163.5 | 305.8 | -851.4*** | -971.1*** | -511.1** | -529.8* |
| | [-3.28] | [-2.89] | [0.90] | [1.61] | [-2.65] | [-2.76] | [-2.35] | [-1.97] |
| $Killings_{20km}^{[t-6;t+5]}$ | 347.2 | 341.3 | -230.2** | -242.1** | 288.5 | 295.1 | 298.5** | 298.8** |
| | [1.60] | [1.60] | [-1.98] | [-2.13] | [1.43] | [1.47] | [2.21] | [2.17] |
| $Killings_{20km}^{[onset;t-7]}$ | 84.92 | 77.50 | 75.74** | 60.45* | -82.26 | -73.57 | 81.98** | 82.39* |
| | [0.90] | [0.78] | [2.13] | [1.75] | [-1.26] | [-1.07] | [2.04] | [1.87] |
| Environment controls | No | Yes | No | Yes | No | Yes | No | Yes |
| Belt-Zone fixed-effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Month fixed-effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 2748 | 2748 | 2748 | 2748 | 2748 | 2748 | 2748 | 2748 |
| Mean dependant variable | 104726.89 | | 50471.61 | | 30482.81 | | 20107.35 | |
| Average effect of killings | -15267.17 | -15163.62 | | | -10272.97 | -11716.25 | -6166.39 | -6392.38 |

Standard errors clustered at the village level, $t$-statistics in brackets, $^{*}p < 0.1$,$^{**}$ $p < 0.05$,$^{***}$ $p < 0.01$

The last lines of the table report average effect of casualties in the last 6 months for coefficient with $p - value \leq 0.10$

The survey details allow decomposing income components and further precise the effect of violence. Decreasing income from non-agricultural labour and transfers - remittances and pensions - accounts for most of the total income reduction. Columns (5) and (6) in table 1.2 show that income generated by non-agricultural labour represents one third of the total annual income and it drops by one third. The fall of transfers in the last two columns is relatively comparable in proportion but smaller in absolute value. There might be a small compensation through agricultural labour income but it is anyway not sufficient to stabilize income as shown in columns (3) and (4).

22. All monetary values are computed on an annual basis. They are expressed in $NPR_{2010}$ using the price deflator proposed by the CBS. Results are not affected by this choice since regional variations in price levels are capture by belt-zones fixed-effects

Labour allocation mirrors changes in income. The time spent by households in non-agricultural wage employment - paid on a daily up to monthly basis - diminishes by 20% on average. Estimations (1) and (2) in table 1.3 indicate that every additional conflict related casualty before the survey reduces wage working time by roughly one workday per year. The effect is almost identical for non-agricultural own-labour but statistically less precisely estimated. Agricultural labour represents the bulk of household annual working time and is stable if not increasing slightly as reported in column (8).

Table 1.3 – Labour allocation in war times (Hours per year)

| | Non-agri. wage labour | | Non-agri. self-labour | | Agri casual labour | | Agri self-labour | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $Killings_{20km}^{[t-6;t-1]}$ | -8.657** | -8.418* | -5.780 | -9.593* | 0.970 | 0.634 | 4.380 | 14.50 |
| | [-2.04] | [-1.93] | [-1.22] | [-1.94] | [0.26] | [0.16] | [0.50] | [1.55] |
| $Killings_{20km}^{[t-6;t+5]}$ | 2.386 | 2.346 | 3.810 | 4.098 | 1.067 | 1.053 | -1.778 | -2.628 |
| | [0.99] | [0.98] | [1.31] | [1.44] | [0.62] | [0.61] | [-0.37] | [-0.56] |
| $Killings_{20km}^{[onset;t-7]}$ | 1.024 | 0.973 | -1.181 | -0.808 | -1.614*** | -1.629*** | 1.735 | 0.640 |
| | [1.30] | [1.20] | [-1.19] | [-0.85] | [-3.18] | [-3.09] | [0.67] | [0.26] |
| Environment controls | No | Yes | No | Yes | No | Yes | No | Yes |
| Belt-Zone fixed-effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Month fixed-effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 2748 | 2748 | 2748 | 2748 | 2748 | 2748 | 2748 | 2748 |
| Mean dependant variable | 541.31 | | 441.67 | | 441.22 | | 3358.66 | |
| Average effect of killings | -104.45 | -101.57 | | -115.74 | | | | |

Standard errors clustered at the village level, $t$-statistics in brackets, $^{*}p < 0.1,^{**} p < 0.05,^{***} p < 0.01$

The last lines of the table report average effect of casualties in the last 6 months for coefficient with $p - value \leq 0.10$

Falling income does affect household consumption. One additional casualty decreases household total annual consumption by 1,344NPR (estimation (2) in table 1.4). This magnitude mirrors the estimated effect on income. The reduction of consumption is only partly related to a drop in frequent consumption expenditures, as reported in columns (3) and (4). However it is not due to a fall of food consumption. Households actually cut their expenses in frequent non-food expenditures - like fuel, transport and personal care -, in infrequent expenses, in durable good acquisition as well as in schooling and health expenditures [23]. The last two columns show that household size is stable. Therefore, the reduction of income and consumption is not

23. Tables available upon request.

driven by the departure of household members. On the contrary, it reflects a real drop in household living conditions.

Table 1.4 – Household consumption in war times ($NPR_{2010}$)

| | Tot. consumption | | Freq. consumption | | Food consumption | | Household size | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $Killings_{20km}^{[t-6;t-1]}$ | -1264.4*** | -1344.3*** | -447.1** | -444.5* | -33.93 | -35.27 | -0.000562 | 0.00241 |
| | [-2.74] | [-2.78] | [-2.06] | [-1.91] | [-0.28] | [-0.27] | [-0.06] | [0.26] |
| $Killings_{20km}^{[t-6;t+5]}$ | 63.13 | 63.25 | 63.05 | 59.94 | -44.53 | -46.68 | 0.00206 | 0.00159 |
| | [0.30] | [0.30] | [0.58] | [0.55] | [-0.71] | [-0.76] | [0.32] | [0.25] |
| $Killings_{20km}^{[onset;t-7]}$ | 189.7*** | 190.2*** | 80.68** | 76.83** | 32.57 | 29.92 | -0.000721 | -0.00131 |
| | [2.63] | [2.64] | [2.36] | [2.19] | [1.43] | [1.28] | [-0.43] | [-0.82] |
| Environment controls | No | Yes | No | Yes | No | Yes | No | Yes |
| Belt-Zone fixed-effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Month fixed-effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 2748 | 2748 | 2748 | 2748 | 2748 | 2748 | 2748 | 2748 |
| Mean dependant variable | 111565.98 | | 85553.99 | | 62977.44 | | 5.34 | |
| Average effect of killings | -15256.04 | -16220.07 | -5394.71 | -5363.53 | | | | |

Standard errors clustered at the village level, $t$-statistics in brackets, $^{*}p < 0.1, ^{**}p < 0.05, ^{***}p < 0.01$

The last lines of the table report average effect of casualties in the last 6 months for coefficient with $p - value \leq 0.10$

**Heterogeneous effects by caste**

The conflict did not affect all groups of the population in the same way. From Maoists rhetoric and deeds, Hindu high castes of the Hills were specific targets. They had therefore specific reasons to be affected and to react in different ways than the overall rural population. I therefore estimate a modified version of equation (1.3) by including a dummy variable indicating whether the household is Brahmin or Chhetry and its interaction with violence measures.

High castes have a significantly higher income on average than others. Their income drops significantly more in conflict times compared to the remaining part of the population. This is true both in absolute value and in proportion. Estimation (2) in table 1.5 shows that the effect of an additional conflict related casualty for the overall population is -1,004NPR. The additional marginal effect for high castes is -1,785NPR. On average, there is a reduction of household income of non-high castes by 12,107NPR. This represents 12% of the average income of this population group. For the high castes, the average net effect on income reaches -33,637NPR.

This amounts to more than 30% of their average income. This average effect should be compared to the 36,684NPR annual household income differential between high caste households and others estimated in (2) by the parameter associated with the high castes indicator variable. In other terms, the short term average effect of the conflict has drastically reduced the income gap between high caste and others.

The large additional reduction of non-agricultural labour income drives most of the differential in the total income decline as shown in estimation (5-6) of table 1.5. Specification (6) tells us that one more killing around the village decreases all household non-agricultural labour income by 771NPR. For high castes, there is a statistically and economically sizeable additional contraction of 1,476NPR. On the other side, non-high caste households generate a slightly higher agricultural labour income since the interaction term for high castes cancels the effect for this last sub-group (columns (3-4)). All households suffer from a reduction of transfers and, in this dimension, there is no difference between high castes and others as shown in columns (7) and (8).

If non-agricultural labour income goes down, especially for high castes, it is directly related to the drop of working time in self-employment in non-agricultural activities. One additional person killed around the village reduces the annual working time of high caste household men by 15 hours, almost two working days. It has no significant effect on the rest of the population. On average in the short-term, the conflict reduces men working time of high caste households in non-farm business activities by more than 200 hours on an annual basis (see specifications (7-8) in table 1.6). Men self-employed labour in agriculture increases by 10 hours per additional killings following violence episodes but only in non-high castes households. It represents a 10% of non-high caste self-employed labour in agriculture [24].

Household size varies differently between high castes and others, with high castes losing their young males while other households size remain stable. The first two columns of table 1.7 report the estimation of household size as a function of conflict intensity. There is no short-term relation between violence and household size for non-high castes households. For high castes, there is a significant negative effect on household size, with an estimated drop of 0.03 members when one additional person

24. The working time in non-agricultural wage labour paid on monthly basis decreases both for high castes and others but not differentially across the two groups. Tables available upon request.

got killed in the surrounding 20km. It means that, on average, and in the short-term, the conflict has pushed one person in every three high caste households to leave it. Columns (3) to (6) indicate that the effect is largely driven by the departure of young males between 16 and 49 years of age. On average, one high caste household out of five loses a productive male[25]. Notice that the departure of productive males is not compensated by hiring workers, as reported in the last two columns of table 1.7. On the contrary, high caste households reduce expenses related to payments compensating agricultural casual workers.

25. Within this broad age class, the effect is larger for younger male but the statistical power goes down as I slice the age classes.

Table 1.5 – Income in war times ($NPR_{2010}$) - Heterogenous effect for Brahmin and Chhetry

| | Total income | | Agri. labour inc. | | Non-Agri. labour inc. | | Transfers | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $Killings_{20km}^{[t-6;t-1]}$ | -970.8** | -1003.5** | 254.8 | 380.3* | -640.4** | -771.3** | -530.4** | -559.9** |
| | [-2.59] | [-2.43] | [1.24] | [1.78] | [-2.28] | [-2.58] | [-2.36] | [-2.03] |
| $H.Caste * Killings_{20km}^{[t-6;t-1]}$ | -1752.9* | -1784.5* | -399.7 | -414.9 | -1467.1* | -1476.1* | 124.3 | 122.8 |
| | [-1.65] | [-1.69] | [-1.22] | [-1.30] | [-1.77] | [-1.82] | [0.25] | [0.25] |
| $Killings_{20km}^{[t-6;t+5]}$ | 285.9 | 282.8 | -215.3 | -227.1* | 193.6 | 201.6 | 321.6** | 323.4** |
| | [1.48] | [1.47] | [-1.63] | [-1.75] | [1.22] | [1.29] | [2.32] | [2.28] |
| $H.Caste * Killings_{20km}^{[t-6;t+5]}$ | 954.7 | 978.6 | -23.44 | -6.860 | 1077.2* | 1079.7* | -161.6 | -161.5 |
| | [1.38] | [1.43] | [-0.12] | [-0.04] | [1.88] | [1.91] | [-0.54] | [-0.55] |
| $Killings_{20km}^{[onset;t-7]}$ | 85.74 | 83.19 | 79.22* | 66.00 | -103.5 | -93.94 | 110.9** | 113.2** |
| | [0.81] | [0.76] | [1.79] | [1.52] | [-1.48] | [-1.29] | [2.29] | [2.14] |
| $H.Caste * Killings_{20km}^{[onset;t-7]}$ | -168.5** | -164.1** | -45.89 | -43.31 | -52.90 | -52.03 | -77.77** | -77.66* |
| | [-2.19] | [-2.12] | [-1.33] | [-1.27] | [-1.06] | [-1.03] | [-2.01] | [-1.97] |
| High Caste | 37579.2*** | 36684.2*** | 20066.2*** | 19057.0*** | 1745.1 | 1985.5 | 14880.9** | 14953.1** |
| | [3.19] | [3.13] | [4.54] | [4.24] | [0.21] | [0.24] | [2.36] | [2.33] |
| Environment controls | No | Yes | No | Yes | No | Yes | No | Yes |
| Belt-Zone fixed-effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Month fixed-effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 2748 | 2748 | 2748 | 2748 | 2748 | 2748 | 2748 | 2748 |
| Mean dep. variable H.caste | 117062.23*** | | 54619.29*** | | 35976.89** | | 21361.66 | |
| Mean dep. variable others | 99117.54 | | 48585.51 | | 27984.44 | | 19536.96 | |
| Avg. effect of killings all | -11713 | -12107.36 | | 4588.73 | -7726.18 | -9306.1 | -6399.71 | -6755.27 |
| Avg. effect of killings H.caste | -21149.39 | -21530.35 | | | -17701.01 | -17809.83 | | |
| Net effect on high caste | -32862.39 | -33637.71 | | | -25427.19 | -27115.94 | | |

Standard errors clustered at the village level, $t$-statistics in brackets, $^{*}p < 0.1,^{**} p < 0.05,^{***} p < 0.01$

The last lines of the table report average effect of casualties in the last 6 months for coefficient with $p - value \leq 0.10$

Table 1.6 – Men labour allocation in war times (Hours per year) - Heterogenous effect for Brahmin and Chhetry

| | Agri. casual labour | | Non-agri. casual labour | | Agri self-employed labour | | Non-agri self-employed labour | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $Killings_{20km}^{[t-6;t-1]}$ | 1.991 | 1.786 | -3.908 | -3.575 | 6.880 | 10.35** | -2.730 | -5.532 |
| | [0.79] | [0.69] | [-1.45] | [-1.30] | [1.52] | [2.17] | [-0.70] | [-1.38] |
| $H.Caste * Killings_{20km}^{[t-6;t-1]}$ | -6.195* | -6.560* | -1.480 | -1.383 | -17.08 | -18.03 | -15.47** | -14.96** |
| | [-1.68] | [-1.75] | [-0.37] | [-0.35] | [-1.41] | [-1.53] | [-2.17] | [-2.15] |
| $Killings_{20km}^{[t-6;t+5]}$ | 0.562 | 0.513 | 0.943 | 0.936 | -0.390 | -0.808 | 1.940 | 2.234 |
| | [0.49] | [0.45] | [0.58] | [0.57] | [-0.17] | [-0.36] | [0.82] | [0.96] |
| $H.Caste * Killings_{20km}^{[t-6;t+5]}$ | 2.122 | 2.405 | -0.510 | -0.576 | 3.855 | 4.730 | 8.406* | 7.900* |
| | [0.91] | [1.01] | [-0.18] | [-0.20] | [0.52] | [0.66] | [1.73] | [1.71] |
| $Killings_{20km}^{[onset;t-7]}$ | -1.431*** | -1.475*** | 1.597** | 1.585** | 0.649 | 0.196 | -1.057 | -0.733 |
| | [-3.43] | [-3.46] | [2.28] | [2.24] | [0.48] | [0.15] | [-1.32] | [-0.99] |
| $H.Caste * Killings_{20km}^{[onset;t-7]}$ | 0.806** | 0.857** | -1.156 | -1.169 | -1.475 | -1.329 | -0.132 | -0.214 |
| | [2.19] | [2.27] | [-1.45] | [-1.47] | [-1.13] | [-1.02] | [-0.17] | [-0.28] |
| High Caste | -166.5*** | -177.5*** | -69.86 | -68.04 | 311.4** | 266.4* | -83.24 | -55.16 |
| | [-3.48] | [-3.58] | [-1.10] | [-1.05] | [2.01] | [1.84] | [-0.88] | [-0.64] |
| Environment controls | No | Yes | No | Yes | No | Yes | No | Yes |
| Belt-Zone fixed-effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Month fixed-effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 2748 | 2748 | 2748 | 2748 | 2748 | 2748 | 2748 | 2748 |
| Mean dep. variable H.caste | 60.85*** | | 136.37*** | | 1422.59** | | 266.54* | |
| Mean dep. variable others | 315.65 | | 296.92 | | 1298.97 | | 331.89 | |
| Avg. effect of killings all | | | | | | 124.83 | | |
| Avg. effect of killings H.caste | -74.75 | -79.15 | | | | | -186.62 | -180.45 |
| Net effect on high caste | | | | | | | -219.56 | -247.19 |

Standard errors clustered at the village level, $t$-statistics in brackets, $^{*}p < 0.1,^{**} p < 0.05,^{***} p < 0.01$

The last lines of the table report average effect of casualties in the last 6 months for coefficient with $p - value \leq 0.10$

Table 1.7 – Household structure in war times - Heterogenous effect for Brahmin and Chhetry

| | Household size | | Men 16-49 | | Women 16-49 | | Agri. labour exp. | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $Killings_{20km}^{[t-6;t-1]}$ | 0.00320 | 0.00688 | -0.00339 | -0.00271 | -0.000243 | -0.000206 | -12.47 | -25.53 |
| | [0.29] | [0.65] | [-0.72] | [-0.58] | [-0.08] | [-0.06] | [-0.42] | [-0.56] |
| $H.Caste * Killings_{20km}^{[t-6;t-1]}$ | -0.0340* | -0.0370* | -0.0139** | -0.0141** | -0.00434 | -0.00493 | -156.2* | -163.2* |
| | [-1.67] | [-1.84] | [-2.20] | [-2.23] | [-0.67] | [-0.77] | [-1.77] | [-1.85] |
| $Killings_{20km}^{[t-6;t+5]}$ | 0.00116 | 0.000355 | 0.00150 | 0.00142 | -0.00118 | -0.00128 | 16.82 | 16.55 |
| | [0.18] | [0.05] | [0.56] | [0.53] | [-0.59] | [-0.64] | [1.00] | [0.97] |
| $H.Caste * Killings_{20km}^{[t-6;t+5]}$ | 0.00905 | 0.0116 | 0.00664* | 0.00683* | 0.00335 | 0.00382 | 110.0* | 115.0* |
| | [0.81] | [1.05] | [1.84] | [1.88] | [0.90] | [1.05] | [1.71] | [1.78] |
| $Killings_{20km}^{[onset;t-7]}$ | 0.000370 | -0.000460 | 0.000823 | 0.000730 | 0.00125** | 0.00114** | -5.990 | -6.056 |
| | [0.17] | [-0.22] | [1.15] | [1.01] | [2.18] | [2.03] | [-1.07] | [-0.94] |
| $H.Caste * Killings_{20km}^{[onset;t-7]}$ | -0.00185 | -0.00140 | -0.00134 | -0.00130 | -0.000989* | -0.000905 | -3.907 | -2.953 |
| | [-0.83] | [-0.61] | [-1.61] | [-1.56] | [-1.68] | [-1.53] | [-0.86] | [-0.60] |
| High Caste | 0.00113 | -0.114 | 0.0293 | 0.0198 | 0.0718 | 0.0525 | 231.7 | 58.13 |
| | [0.00] | [-0.47] | [0.39] | [0.25] | [0.99] | [0.76] | [0.23] | [0.06] |
| Environment controls | No | Yes | No | Yes | No | Yes | No | Yes |
| Belt-Zone fixed-effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Month fixed-effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 2748 | 2748 | 2748 | 2748 | 2748 | 2748 | 2748 | 2748 |
| Mean dep. variable H.caste | 5.04*** | | .98** | | 1.33** | | 2705.56* | |
| Mean dep. variable others | 5.48 | | 1.06 | | 1.32 | | 2509.93 | |
| Avg. effect of killings all | | | | | | | | |
| Avg. effect of killings H.caste | -.41 | -.45 | -.17 | -.17 | | | -1884.6 | -1968.63 |
| Net effect on high caste | -.37 | -.36 | -.21 | -.2 | | | -2035 | -2276.65 |

Standard errors clustered at the village level, $t$-statistics in brackets, $^{*}p < 0.1,^{**} p < 0.05,^{***} p < 0.01$

The last lines of the table report average effect of casualties in the last 6 months for coefficient with $p - value \leq 0.10$

**Mechanisms and robustness**

Violence episodes in the vicinity of households have an immediate negative effect on their non-agricultural income, their consumption expenditures and push productive males of the high castes to leave villages in conflict zones. Behind these measured effects are increased isolation and Maoists' taxes/extortions. Long-term workers in rural areas are, for more than 40%, employed as teachers, health practitioners and civil servants. They are known, identifiable and have a regular source of income. They thus make up easy targets for a rebellion in need of cash. There is small negative effect on casual work outside agriculture. Knowing that 54% of casual workers out of agriculture are engaged in the construction sector, this is far from surprising. The conflict severely affects self-employed businesses out of agriculture, especially for high caste households. These businesses very often are active in the retail trade, the restaurant or the food processing sector [26]. Such occupations require frequent connexions between villages and between villages and urban areas, both to reach suppliers and to attract consumers. Last but not least, transfers, whether they are pensions or remittances, decline. Indeed, someone has to channel them to recipients from distant urban areas. In war times, carrying cash is risky both for the handler and the handled. This explains why they fall, contributing to the sharp decline in household income.

One could wonder whether the decreasing income is not simply attributable to taxation and extortions imposed by the Maoists. This might be part of the story and no question allows to directly address transfers to Maoists. However, looking at various consumption items and at labour allocation, it appears that actual taxation *per se* does not fully explain income reduction. First, income and consumption approaches yield similar estimates of the consequences of violence despite the fact that households are not asked to report a post-tax income. Second, the decomposition of consumption by items shows that the reduction in consumption expenditures is partly driven by education and health expenses. It reflects the income drop of teachers and health workers. Third, real effects in terms of working time mirror income variations [27]. It means that insecurity also affects income through labour reallocation. Fourth, one productive male is missing in every five high caste households. I

26. source: NLSS2, author's calculation.
27. This also reassuring if we would suspect households to strategically under-report their income after violent events.

interpret this fact as a short-term life protection decision and a medium term economic diversification strategy. In the short-term, these males escape violence. In the medium term, they might generate income in other areas and bring it back in some form.

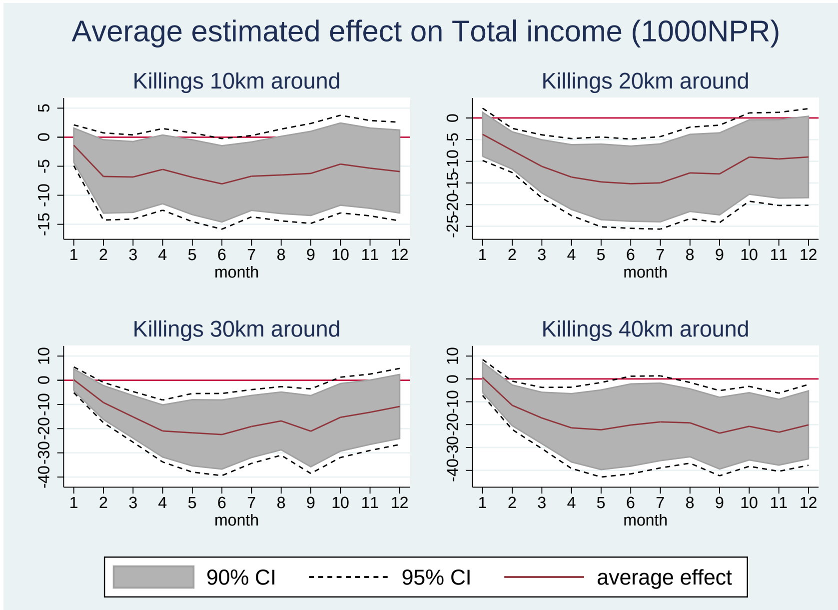
As for migration, the magnitude of the effect could be dampened if (forced) recruitments and conflict casualties were likely to have sizeable effects on household size. Considering the 1,070,000 high caste households living in rural area at the beginning of the 2000's, it means that more than 200,000 productive males left their households in reaction to spikes of violence [28]. It cannot be explained solely by forced recruitments and conflict related casualties. There were less than 14,000 people killed during the conflict and the PLA comprised around 10,000 cadres in 2005 (Mehta and Lawoti, 2010, p.179). This is almost negligible compared to the estimated additional migration, especially if we take into account that Brahmins and Chettrys were not the bulk of recruits in the PLA. Hence, the high number of missing men has to be the result of out-migration. The destination of these migrants is not known. It might result from a displacement effect from risky zones to safer rural areas. While I cannot completely rule out rural to rural migration, most of the displaced people moved to urban centres, where governmental control was sufficient to guarantee a relative security, or to foreign countries.

The mechanisms described here are robust if I modify the month or kilometre window. Figure 1.6 plots the estimated average effect of killings on annual total income, based on equation (1.5), for a one to twelve months window and killings in the ten, 20, 30 and 40 kilometres radius. The average estimated effect of specification (1) in table 1.2 is the six months value of the top right graph. Even if all coefficients in the figure are negative, they become statistically significant only for time windows that are large enough. As the window increases, the effect becomes larger in magnitude and statistically significant. The influence of distance is similar. For short and long distances, estimates are very imprecise. The sharpest effects are estimated for distances between ten and 30 kilometres.

The low precision for small values of $m$ and $\kappa$ is related to the low statistical power. The number of killings before (and after) tends to zero in more and more villages as windows get tighter. For large month windows [29], the effect on total income tends to

28. Source: author's calculation based on NLSS2.
29. I do not extensively discuss the effect of an increased kilometres radius on estimates. The larger $\kappa$ becomes,

Figure 1.6 – Average effect of the conflict on total income




fade out. I interpret this as a progressive absorption of the casualties effect by the overall level of insecurity, which is captured by the killings in the area around the enumeration.

Household size dynamics show persistent effects over time for high castes. For the whole population, as reported in specification (1-2) of table 1.4 and in figure 1.7, household size is relatively stable. The average differential effect for high castes in table specification (1-2) of table 1.7 and in figure 1.8 depicts a clear out-migration in this population subgroup. If the effect is not precisely estimated in the very short-run, it becomes neater as the month window enlarges. It pushes forward a story where the violent episodes of having people killed close by has a ratchet effect on the migration decision. Migration of individuals does not take place immediately but once it occurs, it tends to last.

The framing of questions is also important to understand the time structure of effects. Almost all of the questionnaire is framed in terms of *"past twelve months"* and *"typical month"*. It means that households smooth their answers over the period and therefore reduce the short-term effects of conflict on outcomes. For consistency

the smaller are variations in exposition between villages and precision vanishes.

Figure 1.7 – Average effect of the conflict on household size

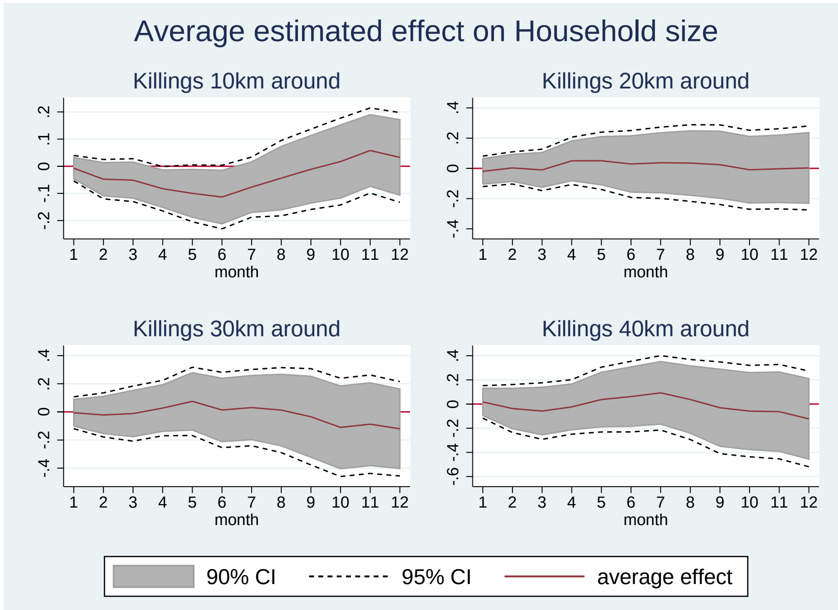
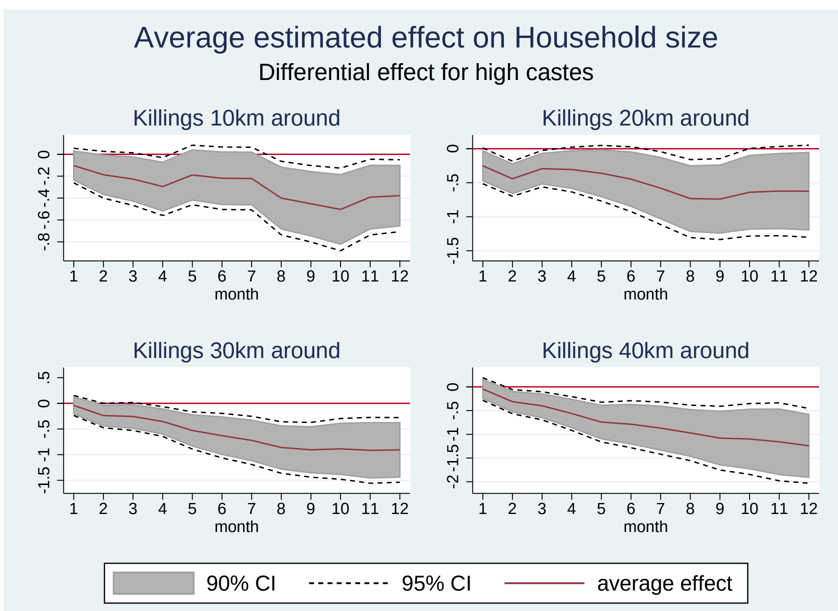



Figure 1.8 – Average differential effect of the conflict on household size for high castes



of measures in the whole survey, I have computed all values on an annual basis. However if I focus on disaggregated measures, short-term measures are more reactive. For instance, health expenditures for illnesses in the last 30 days are more affected than health expenditures for chronic illnesses over the past twelve months. Using the activity roster, I provide, in appendix, estimates of labour allocation in the last seven days. Tables 1.13 and 1.14 respectively mirror tables 1.3 and 1.6. Coefficients go in the same direction and are more precisely estimated.

Interpretations assume up to now that the sample of households is representative of the rural population. Yet, in war times, entire households migrate as well. While I cannot use the cross-section to analyse household migration, the panel allows an indirect measure of potential migration if one looks at attrition. Using the 75 villages of the panel, I can estimate the following model:

$$A_{i2003} = \beta_1 K_{\kappa_v}^{[m-z;m-1]} + \beta_2 K_{\kappa_v}^{[m-z;m+z-1]} + \beta_3 K_{\kappa_{vt}}^{[onset;m-z-1]} + \mathbf{X_i \Phi} + \mathbf{X_i K \Psi} + \lambda_l + \varepsilon_i \tag{1.5}$$

where $A$, a dummy variable indicating whether a household $i$ could not be surveyed in a village selected for the 2003 panel is a function of the number of people killed in the $\kappa$ kilometres around village in the $m$ months before, the $2^{\star}m$ months around and between the onset of the conflict and $m-1$ months before the 2003 survey. A vector of household level controls $\mathbf{X}$ is included and eventually interacted with the three conflict measures. $\lambda$ is a belt-zone specific parameter while $\varepsilon$ is an idiosyncratic term. $\beta$s, $\mathbf{\Phi}$ and $\mathbf{\Psi}$ denote parameters and vector of parameters to estimate.

Table 1.15 indicates that the short-term intensity of the conflict does not increase general attrition. In all specifications, the number of people killed around the village is never statistically significant, and therefore does not contribute, as such to the 14% attrition rate. Conclusions remain similar if I take a more simple measure of the conflict, like the number of people killed between the two rounds of the panel. Still, it is interesting to understand household level correlates of attrition. The second specification of table 1.15 shows that neither pre-war income nor asset holdings allow to predict attrition [30]. Large and non-high caste households have a higher probability to be resurveyed. This differential attrition rate does not impact my conclusions as

30. Pivovarova and Swee (2015) suggest a negative relation between attrition and landholdings but this is driven by a composition effect when urban and rural households are mixed in the same sample.

long as high caste and small households disappear at the same rate whatever the conflict exposure.

Specification (3) shows that despite a higher overall attrition of high caste households, their attrition is smaller in villages witnessing higher conflict intensity. If attrition can be interpreted as household migration, then high caste households migrate less after violent events. On the other side, we already know that productive men do migrate more in these areas. One possible interpretation is that, when high caste households cannot migrate as a whole, they send members at risk out of conflict zones. The last two columns add controls for total income, households size, land ownership and big livestock as well as their interaction with the three measures of conflict. None of the interactions is statistically significant. Results on the main variables are stable [31].

The short-term results are robust to several additional tests. First, removing the number of people killed between the onset of the conflict and seven months before the survey does not alter any conclusions. Actually, estimates are even more precise. This is not a real surprise since belt-zone fixed effects and killings in the window around the survey already control for many factors. Results are also stable if I remove the villages where no one was killed in the six months before or after the survey, reducing the sample by 177 observations. Last, conclusions are unaffected if I remove the killings within the village over the period from the different killings variable. This rules out explanations in which the death within potentially enumerated households could drive the causal mechanism.

## 1.5 Medium term consequences of the conflict

The persistence of short-term adaptation strategies emerges as a natural question after the previous section. How far do immediate responses shape recovery trajectories? Do they affect the development path of a country? Based on the last two survey waves, this section compares household level outcomes between 2003 and 2010 as a function of conflict intensity. I first describe the medium term identification strategy. I then present results showing how the conflict affects households level outcomes in rural areas.

31. All conclusions hold if I use a more simple measure of the conflict, i.e. the number of people killed in the 20km around the village between 1995 and 2003

### 1.5.1 Identification strategy and econometric specification

The richness of the household survey allows following households during and after the war. To understand how they recover, one direct approach is to analyse how changes at the household level are related to variations of conflict intensity in the household's vicinity. In terms of econometric modelling, the relation can be written as:

$$\Delta^{2010-2003}y_i = \alpha\Delta^{2010-2003}Killings_{v_\kappa} + \Delta^{2010-2003}\mathbf{X}_i\psi + \lambda_l + \Delta^{2010-2003}\varepsilon_i \qquad (1.6)$$

in which the difference in the outcome $y$ of household $i$ between 2010 and 2003 is a function of the change over the same period in the number of killings in the $\kappa$ kilometres around the village $v$ where the household lives. $\mathbf{X}$ are time varying control variables. $\lambda$ is a set of five region specific parameters controlling for differential trends at the regional level. It is important because regions are the spatial level of the deflator proposed by the CBS for 2003. It avoids to mix up the effect of inflation - which is potentially affected by the conflict - with the effect of additional casualties. $\varepsilon$ is a household specific component and $\alpha$ and $\psi$ respectively are a parameter and a vector of parameters to estimate.

The first difference removes all unobserved and time unvarying heterogeneity at the household level. Two potential concerns may arise in such specification. First attrition might be conflict specific, something discussed later on. Second, despite the presence of region specific trends, the dependent variable, say income, might still partly be endogenous to the conflict. This would be the case if casualties, in the last years of the war, were concentrated in faster growing areas. A potential solution is to rely on a two-step procedure in which conflict intensity is exogenously predicted in the first step. This is feasible because the People's war specificities provide us with an interesting predictor.

Maoists had financing needs. One of the important income source was the control of timber smuggling to India (ICG, 2005). I therefore propose the price of imported timber in India interacted with the inverse of the distance to the Southern border of Nepal as exogenous predictor of the number of casualties around a surveyed village. The first stage equation is written as

$$K_{tv_\kappa} = \rho K_{t-1,v_{\kappa km}} + \gamma_1 \text{wood price}_{vt} + \gamma_2 \frac{\text{wood price}_{vt}}{\text{distance to India}_v} + \mathbf{X_{vt}}\zeta + \tau_l + \upsilon_v + \eta_{vt} \quad (1.7)$$

where the number of killings $K$ in the $\kappa$ kilometres around the surveyed village $v$ in year $t$ is a function of the number of killings around the same village in the previous period, the price of imported timber in India and the interaction between this price and the inverse of the distance to India. **X** is a vector of controls, including rainfall anomalies and greenness (NDVI). $\tau$ and $\upsilon$ respectively are year-region trends and VDC specific parameters while $\eta$ is an idiosyncratic component.

The exogenous predictor is composed of two parts: the price of timber and the distance between the VDC and India. First, the relevant price of imported timber in India varies spatially across Nepal because there exists different markets for timber and different biomes for trees. ITTO (2013) divides the price of timber in three broad timber categories: coniferous trees, non-coniferous tropical trees and non-coniferous trees (Figure 1.14 draw their variations over time). I match each VDC with the relevant price according to its dominant biome. Second, the distance to India is computed as the distance between a VDC centroid and the Southern border of Nepal. Most of Nepali international trade goes through its Southern border, the Northern border being too mountainous to allow for regular transportation of heavy goods like timber [32]. Following Samuelson (1954), I assume that the transport cost is a share of the traded good total value. The use of the ratio between timber price and distance to India is the econometric translation of the *"iceberg cost"* model. It implies that the value of trade decreases proportionally with the distance to the trading partner.

I estimate equation (1.7) for years between 2001 and 2006. It corresponds to years where the conflict started to expand from Maoists' base areas and to spread over the whole country [33]. The predicted number of casualties is then aggregated over the relevant period and plugged into equation (1.6), the second stage of the two-step procedure. Table 1.8 presents various specifications of equation (1.7), modifying the set of controls. The estimation of the first stage eventually used is presented in

32. Due to the shape and geography of Nepal, flat Western and Eastern borders are negligible.
33. As stated by Maoists, this corresponds to the "strategic balance" and the "strategic offensive" phases of their strategy.

column (4). The coefficient of the interaction between wood price and the inverse of the distance indicates that there were more casualties around surveyed villages as wood price of timber went up, and this was especially true as villages were closer to the Indian border. There were also more killings in years witnessing positive rainfall shocks and where NDVI was larger. It is an indication that the conflict was more intense in areas where agricultural income was potentially higher.

Table 1.8 – Annual number of killings in the 20km around surveyed VDCs between 2001 and 2006

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Lagged $Killings_{20km}$ | 0.00594 | 0.00375 | -0.00424 | -0.0209 |
| | (0.10) | (0.06) | (-0.07) | (-0.36) |
| Indian timber price | | -0.0410*** | -0.0584*** | -0.0528*** |
| | | (-2.99) | (-3.78) | (-3.25) |
| $\frac{\text{Indian timber price}}{\text{Distance to India}}$ | | | 0.624*** | 0.627*** |
| | | | (4.17) | (4.02) |
| NDVI | | | | -0.00609 |
| | | | | (-1.27) |
| Rainfall z-score | | | | 3.292** |
| | | | | (2.27) |
| VDC fixed-effects | Yes | Yes | Yes | Yes |
| Year trend | Yes | Yes | Yes | Yes |
| Observations | 450 | 450 | 450 | 450 |

Standard errors clustered at the village level
$t$-statistics in parentheses, $^{*}p < 0.1, ^{**}p < 0.05, ^{***}p < 0.01$

The validity of an instrument requires both relevance and validity of the exclusion restriction. The exogenous predictor is statistically strong as its $F$-stat of 16.16 is above the commonly accepted threshold of 10. It is also relevant from an historical perspective. As discussed in the context section, timber trade was a source of finance for Maoists. *"The Nepal army and the Maoists needed forest products to maintain their presence in rural areas. They needed fuelwood and grazing for animals and timber for construction, whilst the Maoists needed timber to sell as a source of revenue"* (LFP, 2010). The sign of the coefficient indicates that there were more people killed as the revenue potential of timber went up in a given VDC. Results are thus consistent with anecdotal evidence.

Regarding the exclusion restriction, the instrument should not be directly related to the outcome $y$, conditionally on controls. First, it is very unlikely that the conflict has affected timber prices in India. Nepal is small enough to have a negligible impact on imported timber prices in India. Over the period 2001-2006, India imported more than 20 million cubic meters of industrial round-wood while Nepal officially exported 1,240 cubic meters [34]. Even if illegal trade could have been large, it remains tiny with respect to Indian imports. Second, VDC fixed-effects capture any time unvarying characteristics - like distance to India, hilliness, etc. - which could affect the conflict and be correlated with the instrument. Third, the set of controls includes a year trend and the price of imported timber in India. It allows to capture factors changing over time and potentially correlated with the conflict, like the general rise of conflict intensity over the period and the dynamism of the Indian economy, which is also potentially correlated with wood prices.

Despite this large set of controls, we might still be worried that the instrument directly affect our outcomes of interest. It would be the case if many villagers derive their income from timber exploitation. Higher prices close to India would push their income upwards, attract Maoists and generate a positive correlation between income and casualties. The same type of correlation could arise if "People's Governments" could use their resources to build infrastructure, improve irrigation and reduce poverty.

These channels however are of limited importance. In 2003, only 2.15% of rural households declare to have a non-agricultural business in the forestry sector. There is no evidence that the conflict had a positive effect on running such activities. If any, the conflict even had a deterrent effect on forest resource exploitation. Thapa (2004, p.146) reports that *"traditional livelihood opportunities such as going to the forest to collect non-timber forest produce has been disrupted because anyone found in the forest has been liable to be treated as a Maoist"*. The ability of villagers of going into the forest was reduced by fear of being caught in crossfire between the Maoists and the Nepal Army (LFP, 2010). To answer such concerns, I estimate the relation between wood prices and various pre-conflict outcomes. More precisely, table 1.17 displays results based on the 1996 cross-section and show that the instrument is not correlated with outcomes potentially affected by the demand for industrial round-

34. Source: author's calculation based on ITTO (2013)

wood. Specification (1) shows that income is not correlated with the ratio between timber price in India and the distance to India. It is also true for consumption (Specification (2)), household size (3), non-agricultural income (4) or labour time (6), casual labour income (5) and income from casual labour out of agriculture (7). These results further establish the validity of the strategy.

### 1.5.2 Results

In this subsection, I analyse effects of variations in conflict intensity exposure on a set of rural household level outcomes. Conflict intensity is measured as the number of people killed in the 20 kilometres around the village between the 2003 and 2010 survey wave. Results reported in the next five tables are all presented in the same way. Every table displays estimation results of equation (1.6) for two outcome variables. The first two columns report ordinary least square estimations and the next two report results based on the two-step procedure described in the previous subsection with clustered bootstrapped standard errors based on 500 replications. Columns with even numbers focus on the average effect of killings. Odd columns include an interaction term between killings and an dummy variable indicating whether the household belongs to high caste groups, namely Brahmin and Chettry. They therefore emphasize potentially diverging paths across caste statuses. All regressions include region specific trends, controls for price of timber in India, rain anomalies and NDVI at the village level. Last, all parameters are identified on variations in conflict intensity across time and space in the last year of the war. As in the short-term strategy, all interpretations should be read in terms of deviation with respect to the mean trend. Our paper addresses heterogeneous changes across rural Nepal, not homogenous ones (like the overall decline in poverty or the general out-migration trend).

Self-employment in agriculture is the main occupation in rural Nepal. Between 1995 and 2003, the average self-employed labour time in agriculture has been stable at around 3,350 hours per year and per household. It represents 70% of the average working time in rural areas. Between 2003 and 2010, the self-employed labour time in agriculture went down by 1,400 hours to reach 1,956 hours, which only represented 53% of total working time, as shown in table 1.19. Column (1) of table 1.9 indicates that this reduction is more pronounced in areas where the conflict was more intense.

The estimation of column (2) shows that the story differs across caste status. High castes reduce their working time in self-employed agricultural activities by 6.7 hours more than others for every additional casualty between 2003 and 2010. The average differential effect on high caste working time amounts to 500 hours, more than half of the trend differential between high castes and others. The two-step procedure, reported in column (4) confirms this divergence, even though point estimates are smaller in magnitude than in the OLS estimation. The main difference between the OLS and the two-step procedure is the positive and significant effect of killings on non-high caste households working time in self-employed agricultural occupation.

Table 1.9 – Agricultural labour and income

| | Δ Agricultural self-labour | | | | Δ Agricultural self-income | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $\Delta Killings^{[observed]}_{20km}$ | -3.978 | -1.027 | | | -36.42 | -15.77 | | |
| | [-1.47] | [-0.37] | | | [-0.66] | [-0.30] | | |
| $H.Caste * \Delta Killings^{[observed]}_{20km}$ | | -6.709** | | | | -46.95 | | |
| | | [-2.51] | | | | [-1.31] | | |
| $\Delta Killings^{[predicted]}_{20km}$ | | | 2.705 | 3.133** | | | -30.45 | -24.77 |
| | | | [1.62] | [2.11] | | | [-1.38] | [-1.01] |
| $H.Caste * \Delta Killings^{[predicted]}_{20km}$ | | | | -5.538* | | | | -73.56 |
| | | | | [-1.70] | | | | [-1.02] |
| Environment controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Indian timber price | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Region specific trends | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 744 | 744 | 744 | 744 | 744 | 744 | 744 | 744 |
| Mean change dep. variable H.caste | | −1708.47*** | | | | 68.04** | | |
| Mean change dep. variable others | | -1069.48 | | | | 2332.67 | | |
| Avg.effect of killings all | | | | 358.53 | | | | |
| Avg. effect of killings H.caste | | -500.81 | | -633.86 | | | | |
| Net effect on high caste | | -577.44 | | | | | | |

Standards errors clustered at the village level. $t$-statistics in brackets, $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

Village block-bootstrapped errors based on 500 replications of the two-step estimations.

The last lines of the table report average effect of casualties in the last conflict years for coefficient with $p - value \leq 0.10$

This finding is consistent with short-term results showing that high castes were leaving agriculture while others would invest more into it. It is also in line with the overall trend observable in the cross-section. High castes average working time in self-employed agricultural labour went down from 4,048 hours in 1995 to 3,749 hours in 2003 and 1,928 in 2010. For other households, there is first a slight increase from

2,954 hours in 1995 upto 3,180 hours in 2003 and finally down to 1,970 hours in 2010 (see table 1.20 and 1.21). The differential intensity of the conflict has thus mitigated the drop for non-high caste households.

While beneficial in the short-term, the relatively more important reliance of non-high castes on agriculture proves to be detrimental in the medium term. Column (5) to (8) indicates that an additional conflict related casualty has not increase income generated by self-employment in agriculture. Even if it is not precisely estimated, column (7) suggests that in a village exposed to the average level of violence, households experience an estimated reduction of 3,484NPR, around 10% of the average income generated by self-employment in agriculture. It is however hard to conclude whether high castes, who have reduced their working time in this type of occupation, face a larger drop than other households.

The diverging tracks between high castes and others in terms of agricultural labour allocation transcribes in diverging paths in terms of overall working time, something which can be related to changes in household size. OLS estimations for total working time are reported in table 1.10. Column (2) shows that results are similar to those obtained for self-employed agricultural labour. Estimation (3) shows that households increase their working time by 3.8 hours for every additional casualty in their neighbourhood. This effect is clearly driven by non-high castes as depicted in column (4).

Changes in working time might partly be a consequence of changes in household size. Given the overall negative trend of household size, estimation (6) of table 1.10 suggests that the household size of non-high castes has decreased less in area where the conflict was more intense. In other words, they have maintain their labour force more than high castes in these areas. For high castes, the net effect is not statistically different from 0, if not slightly negative. The two-step procedure yields coefficients of the same sign but of a lower magnitude. Table 1.18 in the appendix shows that this difference across caste status is driven both by the relatively less important departure of productive females and males of the non-high castes. It confirms that the differential reduction of working time is related to changes in the household size and composition.

Given the importance of migration and remittances in the post-war Nepal, the departure of productive household members needs to be related to transfers received

Table 1.10 – Labour force and Household size

| | Δ Work time | | | | Δ Household size | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $\Delta Killings^{[observed]}_{20km}$ | -6.664 | -3.309 | | | 0.00150 | 0.00439* | | |
| | [-1.62] | [-0.78] | | | [0.61] | [1.72] | | |
| $H.Caste * \Delta Killings^{[observed]}_{20km}$ | | -7.629** | | | | -0.00657*** | | |
| | | [-2.19] | | | | [-4.15] | | |
| $\Delta Killings^{[predicted]}_{20km}$ | | | 3.801* | 4.246** | | | 0.00137 | 0.00152 |
| | | | [1.78] | [2.14] | | | [1.14] | [1.13] |
| $H.Caste * \Delta Killings^{[predicted]}_{20km}$ | | | | -5.764 | | | | -0.00192 |
| | | | | [-1.52] | | | | [-0.62] |
| Environment controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Indian timber price | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Region specific trends | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 744 | 744 | 744 | 744 | 744 | 744 | 744 | 744 |
| Mean change dep. variable H.caste | | $-1398.32^{***}$ | | | | $-.63^{**}$ | | |
| Mean change dep. variable others | | -502.47 | | | | -.12 | | |
| Avg.effect of killings all | | | 435.02 | 485.96 | | .33 | | |
| Avg. effect of killings H.caste | | -569.49 | | | | -.49 | | |
| Net effect on high caste | | -816.47 | | | | | | |

Standards errors clustered at the village level. $t$-statistics in brackets, $^{*}p < 0.1$,$^{**}$ $p < 0.05$,$^{***}$ $p < 0.01$

Village block-bootstrapped errors based on 500 replications of the two-step estimations.

The last lines of the table report average effect of casualties in the last conflict years for coefficient with $p - value \leq 0.10$

by rural households. The first four columns of table 1.11 suggest that transfers received by households in areas more intensely affected by the conflict increased less than in other areas. A decomposition of transfers shows that the conflict has reduced the remittances received from Nepal by non-high caste households. One more casualty decreases these in-flows by 20NPR (specification (8)). In the average village, remittances received from Nepal would have been reduced by -2,330NPR, a sizeable amount compared to the 6,900NPR received by an average non-high caste household. For high castes, the net effect of killings is not statistically different from zero.

Table 1.12 suggests that the conflict has increased the income and consumption gap between high castes and others[35]. OLS estimates for both income and consumption per capita show that high castes in conflict area have done much better in terms of income and consumption per capita that other households. An additional casualty raises high castes' income per capita by 169NPR and consumption per capita

35. Per capita measures are build using different weights for household members. The first adult is fully weighted, other adults have 80% of the first adult weight, children between 6 and 16 years of age 50% and children under 6 receives no weight. The use of the number of members as measure of household size does not affect the conclusions.

by 324NPR more than others. The net effect of the violence on high castes' income in an average village is to increase per capita income by 13,634NPR and consumption per capita by 23,805NPR which correspond respectively to one third and 40% of the average income and consumption per capita in 2010 for this subgroup of the population. Estimations using the two-step procedure are less precise and of a lower magnitude but go in the same direction. The reduction in the size of coefficients might indicate that violence in the last year of the conflict was more concentrated in areas where inequalities between high castes and others were growing, an argument consistent with Macours (2011).

Table 1.11 – Transfers and remittances

| | Δ Transfers | | | | Δ Remittances from Nepal | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $\Delta Killings^{[observed]}_{20km}$ | 83.80 | 59.74 | | | 12.11 | -23.03 | | |
| | [1.14] | [0.66] | | | [0.42] | [-0.85] | | |
| $H.Caste * \Delta Killings^{[observed]}_{20km}$ | | 54.71 | | | | 79.89** | | |
| | | [0.62] | | | | [2.24] | | |
| $\Delta Killings^{[predicted]}_{20km}$ | | | -40.07 | -45.79 | | | -20.36** | -26.20*** |
| | | | [-1.39] | [-1.64] | | | [-2.07] | [-2.59] |
| $H.Caste * \Delta Killings^{[predicted]}_{20km}$ | | | | 74.12 | | | | 75.67 |
| | | | | [0.94] | | | | [1.41] |
| Environment controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Indian timber price | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Region specific trends | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 744 | 744 | 744 | 744 | 744 | 744 | 744 | 744 |
| Mean change dep. variable H.caste | | 22583.18** | | | | 11039.53*** | | |
| Mean change dep. variable others | | 17662.54 | | | | 2424.72 | | |
| Avg.effect of killings all | | | | | | | -2329.74 | -2998.45 |
| Avg. effect of killings H.caste | | | | | | 5963.59 | | |
| Net effect on high caste | | | | | | | | |

Standards errors clustered at the village level. $t$-statistics in brackets, $^{*}p < 0.1$,$^{**}$ $p < 0.05$,$^{***}$ $p < 0.01$

Village block-bootstrapped errors based on 500 replications of the two-step estimations.

The last lines of the table report average effect of casualties in the last conflict years for coefficient with $p - value \leq 0.10$

Table 1.12 – Total income and consumption per capita

| | Δ Income per adj. capita | | | | Δ Consumption per adj. capita | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $\Delta Killings_{20km}^{[observed]}$ | 88.21 | 14.04 | | | 137.7 | -4.648 | | |
| | [1.28] | [0.21] | | | [1.56] | [-0.06] | | |
| $H.Caste * \Delta Killings_{20km}^{[observed]}$ | | 168.6* | | | | 323.6*** | | |
| | | [1.95] | | | | [3.11] | | |
| $\Delta Killings_{20km}^{[predicted]}$ | | | -35.05 | -45.11* | | | -43.72 | -59.33 |
| | | | [-1.33] | [-1.79] | | | [-1.00] | [-1.26] |
| $H.Caste * \Delta Killings_{20km}^{[predicted]}$ | | | | 130.2 | | | | 202.2 |
| | | | | [0.91] | | | | [1.36] |
| Environment controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Indian timber price | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Region specific trends | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 744 | 744 | 1194 | 1194 | 744 | 744 | 1194 | 1194 |
| Mean change dep. variable H.caste | | 29543.2** | | | | 47415.56*** | | |
| Mean change dep. variable others | | 18400.02 | | | | 27558.62 | | |
| Avg.effect of killings all | | | | -5162.83 | | | | |
| Avg. effect of killings H.caste | | 12586.24 | | | | 24152.43 | | |
| Net effect on high caste | | 13634.47 | | | | 23805.51 | | |

Standards errors clustered at the village level. $t$-statistics in brackets, $^{*}p < 0.1,^{**} p < 0.05,^{***} p < 0.01$

Village block-bootstrapped errors based on 500 replications of the two-step estimations.

The last lines of the table report average effect of casualties in the last conflict years for coefficient with $p - value \leq 0.10$

### 1.5.3 Discussion

In light of the previous results, we have both immediate responses in times of war - the short-term - and changes between war time and peace time, as a function of conflict intensity - the so-called medium term. This section discusses the latter in light of the former.

Immediately after violence episodes, I showed that total income drops. Transfers in the form of remittances and pensions fall. Households reduce their working time in non-agricultural activities and register a sizeable loss of income paid on a regular basis. High castes experience a larger reduction of self-employed non-farm activities and income.

To address the immediate reduction of income, high caste households adopt different strategies than other households, a divergence which has consequences on post-war recovery trajectories. Both types of households react in the short-run by reducing their consumption expenditures, especially for non-food frequent expenditures like fuel, transport or schooling and for infrequent expenditures such as health or durable acquisition. Non-high castes also react by allocating more labour time in agriculture. It eventually generates additional income and dampens the short-term income contraction. High castes adopt a distinct strategy. They send productive males out of the household. It reduces their labour force but also their consumption needs. However, increased migration does not generate immediate returns in terms of remittances inflows. Instead, in the short-term, high castes register a larger fall of their total income.

Three years after the war ended, non-high caste households in conflict zones continue to allocate more working time in self-employed agricultural occupations. This contrasts with high castes who do not rely more on agriculture. While the "agricultural" strategy was beneficial for the non-high castes in the short-run, it does not translate in a higher agricultural income. Actually, agricultural income increases less in conflict zones affected by the conflict than elsewhere. This lower growth can be directly related to a rise in agricultural labour expenditures [36]. This reduction of agricultural income is true for both types of households but high castes have other strategies to avoid negative consequences on their living standards.

High castes rely more than others on migration. This trend has already been observed in the short term and remains after the peace agreement. This differential migration affects productive members and, while it was more important for men in the short-run, it is not gender specific in the medium term. It suggests that males are the first to leave - it is also riskier for them to stay - and females tend to depart later on. The relative reduction of household size among high castes pushes their income and consumption per capita upwards. The migration channel can also be interpreted as an income diversification strategy improving the safety net of staying household members. High caste rural households in conflict zones do not receive less remittances from people living in Nepal. One can argue that migration within the country is less risky than migration to foreign countries, even if the latter has higher returns, conditionally on success. Last but not least, high caste households retrieve jobs paid on a regular basis which contributes to a reduced volatility of their income [37].

36. Additional tables available upon request
37. Table for permanent jobs available upon request.

For non-high caste households, the post-war situation looks gloomier. On average, their total remittances in-flow are not affected by the conflict. But, they receive less remittances from Nepal, which suggests a higher variance of inflows across households. Migration abroad is more uncertain than migration within the country, both for the migrant and for the potential recipient of remittances. Their larger reliance on agriculture in the short-term does not generate additional revenue. On the contrary, they face higher operational costs following the rise in agricultural labour expenditures, thereby reducing agricultural income.

The medium run analysis teaches us that the adverse effects of the conflict prove to be stronger and more persistent for non-high caste households. The relative labour intensification in agriculture has set non-high caste households on a path which, despite appearing beneficial in the short-run ends up being detrimental after conflict resolution. On the other hand, high castes lose more during the conflict but their short-term adaptation strategies help them to recover quickly once peace settles.

### 1.5.4 Robustness and validity of the strategy

The medium term strategy is subject to two main potential biases arising from sample selection related to the conflict and from potential threats to the validity of the instrument. Table 1.16 reports an analysis of household attrition in the third wave of the panel. The dependent variable is a dummy variable indicating whether a household surveyed in 2003 could not be surveyed again in 2010. The conflict never seems to increase attrition and the conclusion holds through in the two-step procedure. The size of households and livestock holdings are the most robust determinants of attrition. It is however unlikely to affect the conclusions of the previous analysis. Column (5-6) show that there is no differential attrition of small households in villages more severely affected by the conflict. The coefficient of household size is extremely stable when its interaction with conflict intensity is introduced in column (6).

The two-step procedure has particularly large effects when income is at play. Coefficients switch from a positive correlation between the conflict and the increase of total income and transfers to a negative effect of violence. This is consistent with a story where violence was more intense in areas where income was growing the most, and eventually where the differential growth rate of income was the largest between high castes and others. This is in line with the argument developed in Macours (2011). Notice also that the main concern with the exclusion restriction was that the price of imported timber would directly and positively affect household income. If so, then the instrument should reduce the negative effect of the conflict on income, which is clearly not the case here. The relation between agricultural self-employed labour and the conflict is also affected by the two-step procedure, even though the differential between high castes and others is very stable. It suggests that most of the casualties in the last years of the conflict were concentrated in areas where the agricultural transition was more advanced.

Last but not least, it should be clear that the analysis never claims to be exhaustive nor to reflect the total effect of the conflict on rural households. For instance, data are insufficient to shed light on psychological costs associated with the uncertainty of violence or of migration. Both identification strategies rely on variations in conflict intensity within Nepal. Yet, the civil war affected the whole country and there exists no perfect counter-factual, i.e. a peaceful Nepal over the same time span. It remains hard to analyse changes which have homogeneously affected the country such as overall migratory movement out of rural areas, the general under-provision of some public goods or the anticipated end of aid programs across the country. All discussions are based on variations over time and space in the number of killings within the same country.

## 1.6 Conclusion

I have confirmed and shown to what extent more intense episodes of violence during the People's War have, in the short-term, significantly reduce household income, particularly for high caste households, a declared target of the Maoists. The drop of income is driven by the reduction of revenue derived from non-agricultural activities and transfers. High castes lose more because their income generated by self-employed non-agricultural occupations sharply declines. In reaction to episodes of violence, productive males of the high castes leave their village while non-high caste households allocate more time to agricultural labour which slightly dampens their income loss. Violence has large and immediate consequences on all rural households living around. In the short-term, everyone loses, and high castes even more, thereby reducing inequalities. In the medium term however, there is a reversal of fortune and distributional effects of the conflict go against non-high castes. High caste households recover faster by reshuffling their capital. Migration appears as a key mechanism in the capital re-composition. It is also striking to see that, even if migration abroad is highly profitable conditionally on success, rural high castes do not directly invest in this strategy following violence episodes. Migration within Nepal appears as a less risky strategy. For non-high castes, the short-term labour intensification in agriculture is not sufficient to generate long term gains in this sector, often presented as key in rural development strategies.

Nepal emerges from the war but neither war nor peace has healed the country from its wounds. If inequalities were fuelling the conflict, it is not clear at all that the war has helped to reduce them. In the long-term, a fast convergence between income groups remain unlikely in Nepal, such as the ones described for Vietnam by Miguel and Roland (2011). Obviously, this paper cannot address nationwide policies such as political emancipation of formerly neglected ethnic groups or investment in infrastructure across the whole country. Hence, the current study highlights that violence cannot, on its own, create a more egalitarian society, even if it is the alleged goals of one of the parties at war. It might eventually redistribute political power, a potential tool to shape a new society. But from means to ends, there is a long way, many directions and up to now, little guidance by politicians in Nepal or researchers. What remains is a lot of uncertainty for citizens.

## 1.7 Appendix

Figure 1.9 – Surveyed rural villages in NLSS2, administrative zones and ecological belt of Nepal

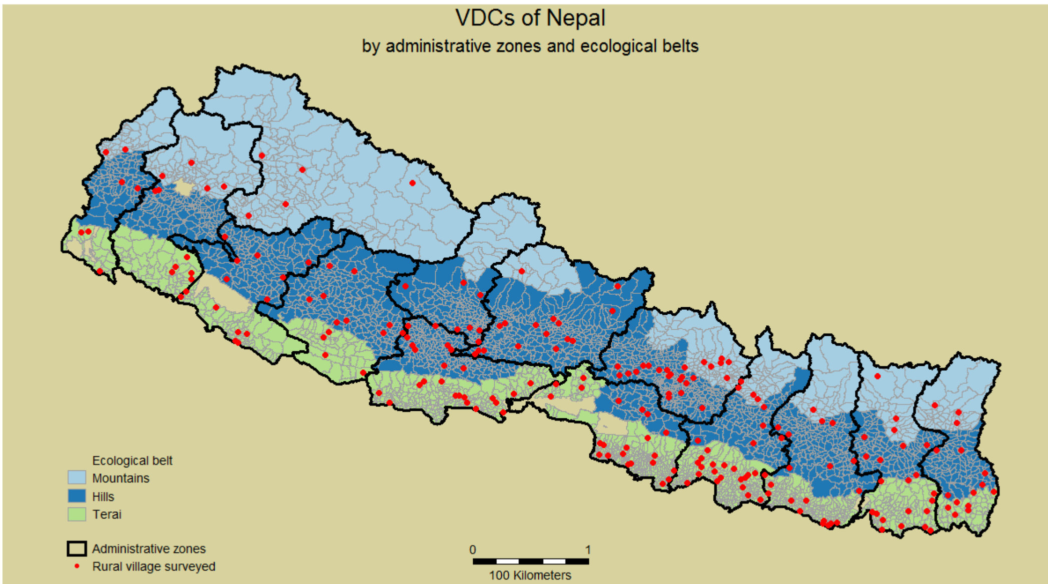


Figure 1.10 – Number of killings and villages surveyed in the first quarter of NLSS2

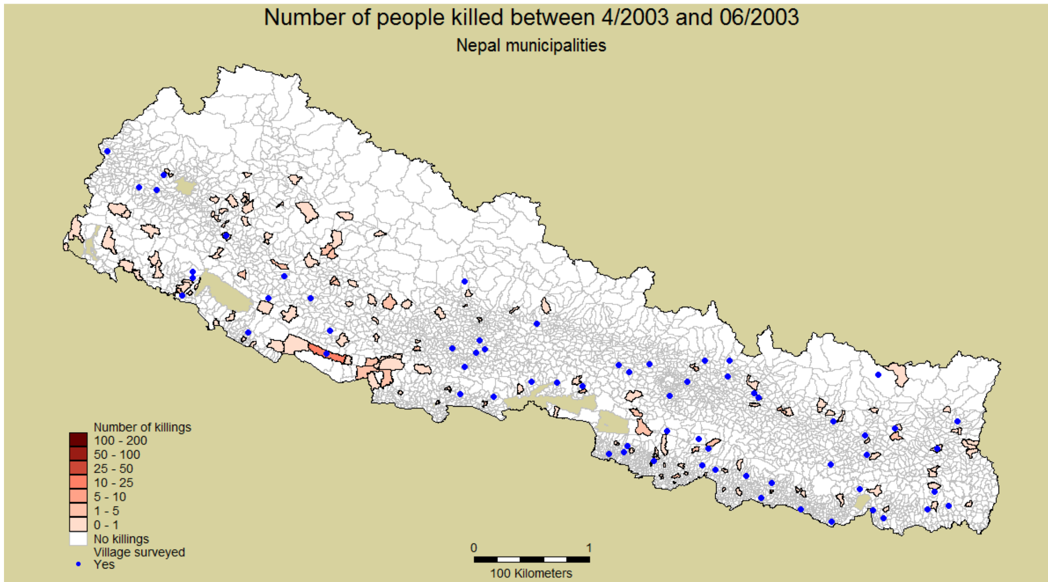



Figure 1.11 – Number of killings and villages surveyed in the second quarter of NLSS2

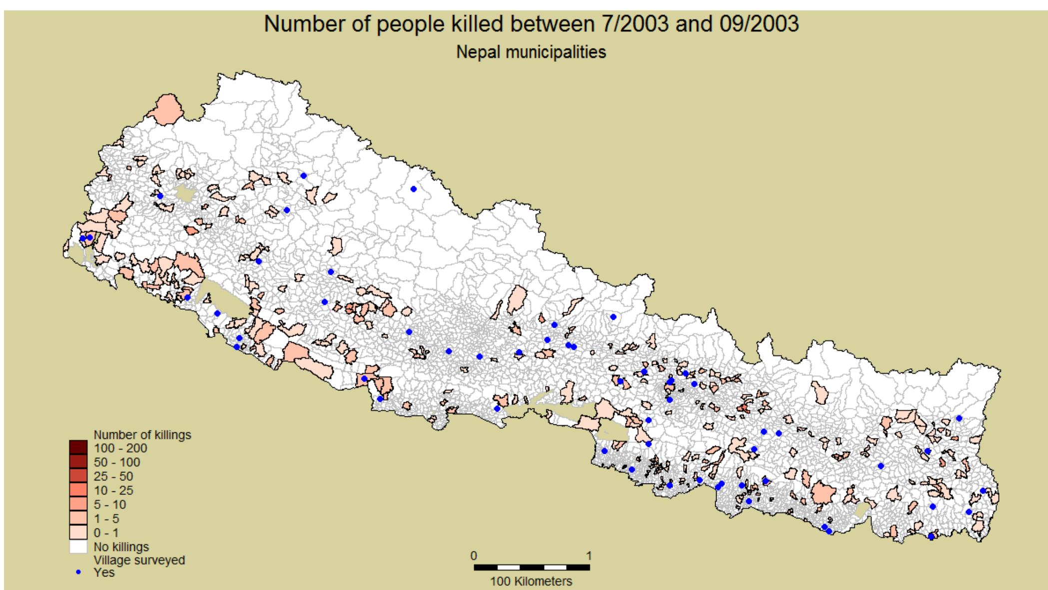


Figure 1.12 – Number of killings and villages surveyed in the third quarter of NLSS2

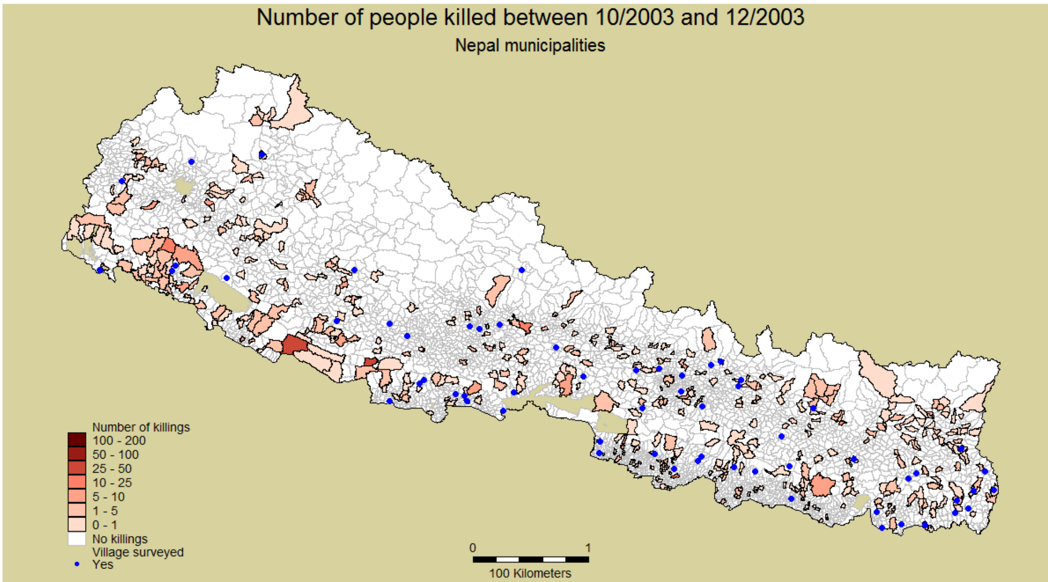



Figure 1.13 – Number of killings and villages surveyed in the last four months of NLSS2

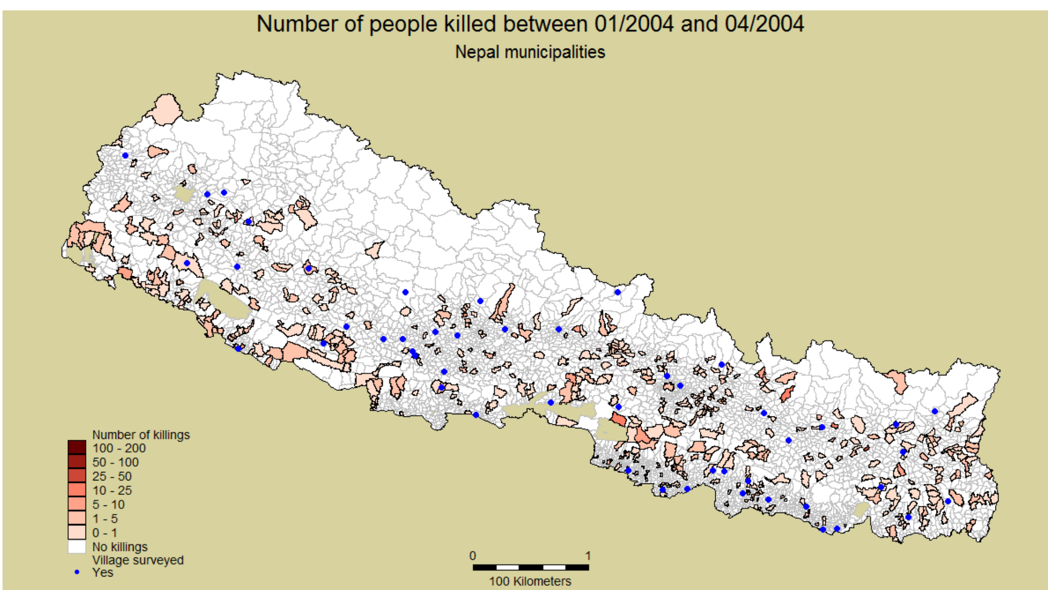


Figure 1.14 – Evolution of imported timber price in India

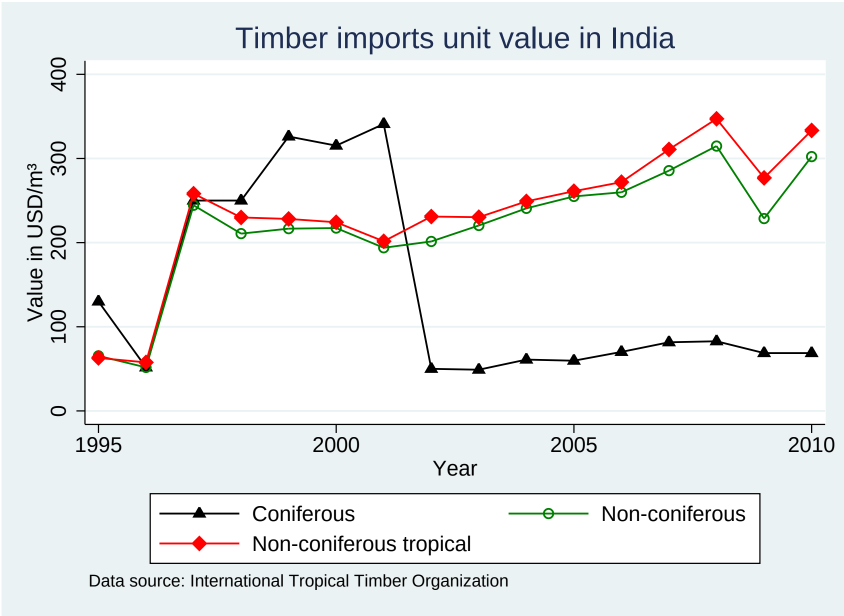



Figure 1.15 – Average effect of the number of killings on the probability to survey a village in a given month

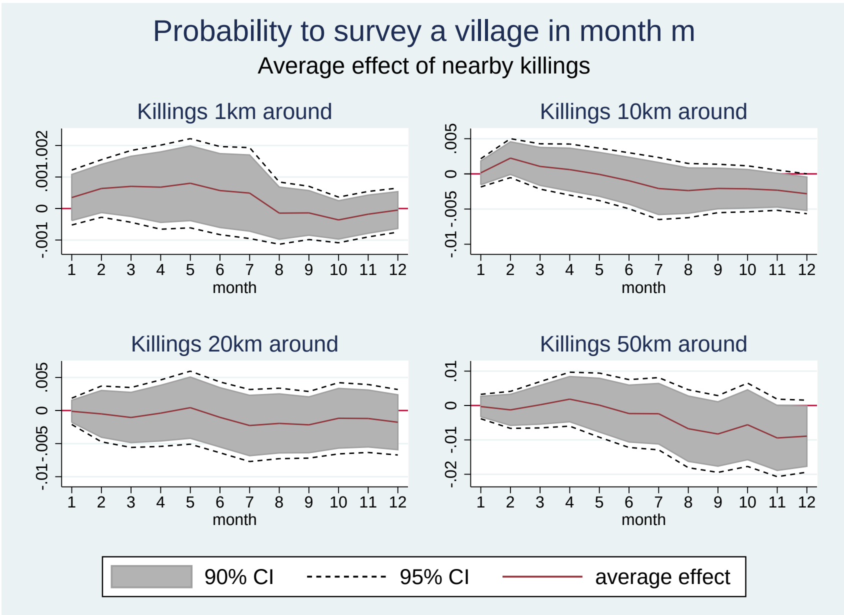


Table 1.13 – Last 7 days labour allocation in war times (Hours per week)

| | Non-agri. wage labour | | Non-agri. self-labour | | Agri casual labour | | Agri self-labour | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $Killings_{20km}^{[t-6;t-1]}$ | -0.165* | -0.132 | -0.143 | -0.266** | 0.0401 | 0.0438 | 0.185 | 0.379 |
| | [-1.69] | [-1.30] | [-1.39] | [-2.48] | [0.37] | [0.40] | [0.73] | [1.32] |
| $Killings_{20km}^{[t-6;t+5]}$ | 0.0517 | 0.0499 | 0.0863 | 0.0966 | -0.000746 | -0.00263 | -0.0365 | -0.0535 |
| | [0.95] | [0.92] | [1.36] | [1.56] | [-0.01] | [-0.05] | [-0.27] | [-0.39] |
| $Killings_{20km}^{[onset;t-7]}$ | 0.0375** | 0.0352* | -0.0368 | -0.0235 | -0.0367** | -0.0390** | 0.0342 | 0.0123 |
| | [2.10] | [1.91] | [-1.30] | [-0.96] | [-2.28] | [-2.37] | [0.48] | [0.19] |
| Environment controls | No | Yes | No | Yes | No | Yes | No | Yes |
| Belt-Zone fixed-effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Month fixed-effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 2748 | 2748 | 2748 | 2748 | 2748 | 2748 | 2748 | 2748 |
| Mean dependant variable | 9.96 | | 9.49 | | 8.45 | | 78.25 | |
| Average effect of killings | -2 | | | -3.21 | | | | |

Standard errors clustered at the village level, $t$-statistics in brackets, $^{*}p < 0.1,^{**} p < 0.05,^{***} p < 0.01$

The last lines of the table report average effect of casualties in the last 6 months for coefficient with $p - value \leq 0.10$

Table 1.14 – Last 7 days men labour allocation in war times (Hours per week) - Heterogenous effect for Brahmin and Chhetry

| | Agri. casual labour | | Non-agri. casual labour | | Agri self-labour | | Non-agri self-labour | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $Killings_{20km}^{[t-6;t-1]}$ | 0.0917 | 0.0967 | -0.0771 | -0.0537 | 0.182 | 0.260* | -0.0602 | -0.160* |
| | [1.09] | [1.15] | [-0.97] | [-0.68] | [1.32] | [1.74] | [-0.71] | [-1.87] |
| $H.Caste * Killings_{20km}^{[t-6;t-1]}$ | -0.131 | -0.143 | -0.0396 | -0.0308 | -0.476 | -0.510* | -0.376** | -0.352** |
| | [-1.35] | [-1.48] | [-0.40] | [-0.30] | [-1.52] | [-1.70] | [-2.41] | [-2.43] |
| $Killings_{20km}^{[t-6;t+5]}$ | -0.0203 | -0.0228 | 0.0284 | 0.0282 | 0.00348 | -0.00801 | 0.0368 | 0.0481 |
| | [-0.51] | [-0.58] | [0.62] | [0.62] | [0.06] | [-0.13] | [0.75] | [1.02] |
| $H.Caste * Killings_{20km}^{[t-6;t+5]}$ | 0.0579 | 0.0682 | 0.00155 | -0.00467 | 0.0656 | 0.0949 | 0.217* | 0.195** |
| | [1.07] | [1.24] | [0.02] | [-0.07] | [0.35] | [0.53] | [1.94] | [2.07] |
| $Killings_{20km}^{[onset;t-7]}$ | -0.0356*** | -0.0382*** | 0.0474** | 0.0469** | 0.00372 | -0.00850 | -0.0436* | -0.0312 |
| | [-2.99] | [-3.14] | [2.21] | [2.18] | [0.11] | [-0.27] | [-1.78] | [-1.64] |
| $H.Caste * Killings_{20km}^{[onset;t-7]}$ | 0.0259*** | 0.0277*** | -0.0246 | -0.0257 | -0.0124 | -0.00743 | 0.0121 | 0.00839 |
| | [3.20] | [3.36] | [-1.17] | [-1.22] | [-0.48] | [-0.29] | [0.69] | [0.49] |
| High Caste | -4.225*** | -4.656*** | -2.174 | -1.981 | 6.419 | 5.017 | -3.606 | -2.438 |
| | [-3.43] | [-3.66] | [-1.33] | [-1.16] | [1.63] | [1.41] | [-1.36] | [-1.28] |
| Environment controls | No | Yes | No | Yes | No | Yes | No | Yes |
| Belt-Zone fixed-effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Month fixed-effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 2748 | 2748 | 2748 | 2748 | 2748 | 2748 | 2748 | 2748 |
| Mean dep. variable H.caste | .83*** | | 2.52*** | | 32.41** | | 5.57* | |
| Mean dep. variable others | 5.94 | | 6.17 | | 30.31 | | 7.02 | |
| Avg. effect of killings all | | | | | | 3.14 | | -1.93 |
| Avg. effect of killings H.caste | | | | | | -6.15 | -4.54 | -4.25 |
| Net effect on high caste | | | | | | | -5.26 | -6.18 |

Standard errors clustered at the village level, $t$-statistics in brackets, $^{*}p < 0.1,^{**} p < 0.05,^{***} p < 0.01$

The last lines of the table report average effect of casualties in the last 6 months for coefficient with $p - value \leq 0.10$

Table 1.15 – Household attrition in the panel between 1995 and 2003

| Dep. variable: Dummy variable indicating that a panel household is not surveyed in 2003 | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| $Killings^{[t-6;t-1]}_{20km}$ | 0.00155 | 0.00264 | 0.00342 | -0.000841 | -0.000432 |
| | [0.77] | [1.39] | [1.51] | [-0.15] | [-0.08] |
| $Killings^{[t-6;t+5]}_{20km}$ | -0.00127* | -0.00150** | -0.000894 | -0.000280 | -0.000581 |
| | [-1.88] | [-2.33] | [-1.23] | [-0.17] | [-0.34] |
| $Killings^{[onset;t-7]}_{20km}$ | 0.000329 | 0.000289 | 0.000467 | 0.000926 | 0.000829 |
| | [0.75] | [0.64] | [1.03] | [1.36] | [1.15] |
| High Caste | | 0.0621** | 0.178*** | 0.194*** | 0.213*** |
| | | [2.20] | [3.39] | [3.67] | [4.17] |
| Tot. $income_{1995}$ | | -0.000164 | | -0.00130 | -0.00150* |
| (1000NPR) | | [-0.45] | | [-1.52] | [-1.70] |
| Household $size_{1995}$ | | -0.0243*** | | -0.0213*** | -0.0201*** |
| | | [-5.73] | | [-3.22] | [-2.89] |
| Land $owned_{1995}$ | | 0.00952 | | | 0.0192 |
| (Hectares) | | [1.26] | | | [1.36] |
| Big $livestock_{1995}$ | | -0.00712 | | | -0.0114 |
| | | [-1.46] | | | [-1.22] |
| H.Caste$\star Killings^{[t-6;t-1]}_{20km}$ | | | -0.00501** | -0.00483** | -0.00537** |
| | | | [-2.01] | [-2.05] | [-2.24] |
| H.Caste$\star Killings^{[t-6;t+5]}_{20km}$ | | | -0.00108 | -0.00133 | -0.00120 |
| | | | [-1.10] | [-1.35] | [-1.19] |
| H.Caste$\star Killings^{[onset;t-7]}_{20km}$ | | | -0.000509 | -0.000641 | -0.000727 |
| | | | [-1.00] | [-1.30] | [-1.47] |
| Belt-zone fixed effects | Yes | Yes | Yes | Yes | Yes |
| Killings$\star$Total income | No | No | No | Yes | Yes |
| Killings$\star$Household size | No | No | No | Yes | Yes |
| Killings$\star$Land owned | No | No | No | No | Yes |
| Killings$\star$Big livestock | No | No | No | No | Yes |
| Observations | 920 | 920 | 920 | 920 | 920 |

Standard errors clustered at the village level $t$-statistics in brackets, $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 1.16 – Household attrition in the panel between 2003 and 2010

| | (1) OLS | (2) 2Step | (3) OLS | (4) 2Step | (5) OLS | (6) 2Step |
|---|---|---|---|---|---|---|
| $\Delta Killings_{20km}$ | -0.000385 | 0.000208 | -0.000478 | 0.000205 | -0.00122 | 0.0000398 |
| | [-0.86] | [0.87] | [-1.17] | [0.96] | [-1.64] | [0.09] |
| High Caste$_{2003}$ | | | 0.0160 | 0.00859 | -0.0116 | -0.00276 |
| | | | [0.54] | [0.28] | [-0.19] | [-0.07] |
| Household size$_{2003}$ | | | -0.0164*** | -0.0169*** | -0.0131 | -0.0170** |
| | | | [-3.03] | [-2.95] | [-1.05] | [-2.54] |
| Total income (1000NPR)$_{2003}$ | | | 0.0000664 | 0.0000552 | -0.0000997 | -0.0000712 |
| | | | [0.53] | [0.43] | [-0.38] | [-0.49] |
| Land owned (Ha)$_{2003}$ | | | 0.00144 | 0.00104 | | |
| | | | [0.16] | [0.12] | | |
| Big livestock$_{2003}$ | | | -0.0125** | -0.0113** | | |
| | | | [-2.39] | [-2.07] | | |
| $\Delta K_{20km}$ * H.Caste | | | | | 0.000238 | -0.000132 |
| | | | | | [0.33] | [-0.21] |
| $\Delta K_{20km}$ * HH size | | | | | -0.0000123 | 0.0000270 |
| | | | | | [-0.10] | [0.56] |
| $\Delta K_{20km}$ * Tot. inc. | | | | | 0.000000816 | 0.000000580 |
| | | | | | [0.29] | [0.43] |
| *Delta* Timber price | Yes | Yes | Yes | Yes | Yes | Yes |
| Distance to India | Yes | Yes | Yes | Yes | Yes | Yes |
| $\Delta$ Environment controls | Yes | Yes | Yes | Yes | Yes | Yes |
| Region fixed effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 843 | 843 | 843 | 843 | 843 | 843 |

Standard errors clustered at the village level, $t$-statistics in brackets, $^{*}p < 0.1,^{**} p < 0.05,^{***} p < 0.01$
In even columns, village block-bootstrapped errors based on 500 replications of the two-step estimations.

Table 1.17 – Orthogonality between the instrument and pre-conflict outcomes

| | (1) Income | (2) Consumpt° | (3) Hh. size | (4) NAgri. self-inc. | (5) Cas. labor inc. | (6) NAgri. self-labor | (7) NAgri. cas. labor |
|---|---|---|---|---|---|---|---|
| $\frac{\text{Indian timber price}}{\text{Distance to India}}$ | -130.8 | -215.6 | -0.00312 | -72.68 | 177.1 | -0.807 | 0.904 |
| | [-0.45] | [-1.12] | [-0.47] | [-0.56] | [1.19] | [-0.18] | [0.58] |
| Distance to India | -258.6*** | -156.1*** | -0.0104*** | -12.88 | -46.15 | -1.642 | 1.371** |
| | [-3.18] | [-3.09] | [-4.29] | [-0.27] | [-1.44] | [-1.60] | [2.07] |
| Indian timber price | -111.5 | 4.271 | -0.00158 | -65.30 | -15.00 | -0.625 | -0.686 |
| | [-0.99] | [0.07] | [-0.59] | [-0.83] | [-0.44] | [-0.54] | [-0.85] |
| Region fixed effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 2559 | 2559 | 2559 | 2559 | 2559 | 2559 | 2559 |

Standard errors clustered at the village level, $t$-statistics in parentheses, $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 1.18 – Number of males and productive females in the household

| | Δ Number of males | | | | Δ Number of women aged 15-49 | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| $\Delta Killings^{[observed]}_{20km}$ | -0.00151 | -0.000312 | | | 0.000537 | 0.00153 | | |
| | [-1.13] | [-0.19] | | | [0.46] | [1.08] | | |
| $H.Caste * \Delta Killings^{[observed]}_{20km}$ | | -0.00273** | | | | -0.00227*** | | |
| | | [-2.57] | | | | [-2.75] | | |
| $\Delta Killings^{[predicted]}_{20km}$ | | | 0.00108 | 0.00119 | | | 0.000538 | 0.000666 |
| | | | [1.29] | [1.28] | | | [0.99] | [1.25] |
| $H.Caste * \Delta Killings^{[predicted]}_{20km}$ | | | | -0.00147 | | | | -0.00165 |
| | | | | [-0.74] | | | | [-1.45] |
| Environment controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Indian timber price | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Region specific trends | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 744 | 744 | 744 | 744 | 744 | 744 | 744 | 744 |
| Mean change dep. variable H.caste | $-.35^{**}$ | | | | $-.18^{***}$ | | | |
| Mean change dep. variable others | -.07 | | | | .04 | | | |
| Avg.effect of killings all | | | .12 | | | | | |
| Avg. effect of killings H.caste | | -.2 | | | | -.17 | | -.19 |
| Net effect on high caste | | -.23 | | | | | | |

Standards errors clustered at the village level. $t$-statistics in brackets, $^{*}p < 0.1,^{**} p < 0.05,^{***} p < 0.01$

Village block-bootstrapped errors based on 500 replications of the two-step estimations.

The last lines of the table report average effect of casualties in the last conflict years for coefficient with $p - value \leq 0.10$

Table 1.19 – Descriptive statistics: household level variables

| Variable | 1996 | | | 2003 | | | 2010 | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Median | | Mean | Median | | Mean | Median |
| Total income | 84746.90 | 63767.3 | *** | 104726.89 | 76233.34 | *** | 178014.46 | 112583.7 |
| | (107672.32) | | | (111557.83) | | | (308770.77) | |
| High Caste | .35 | 0 | *** | .31 | 0 | *** | .33 | 0 |
| | (.48) | | | (.46) | | | (.47) | |
| Agri. labour inc. | 53798.16 | 41459.76 | ** | 50471.61 | 41476.32 | *** | 54912.08 | 39906.89 |
| | (54355.36) | | | (44544.48) | | | (79089.97) | |
| Agri. self-inc. | 31895.02 | 21143.36 | *** | 28471.36 | 19927.88 | *** | 32467.15 | 21447.4 |
| | (39729.44) | | | (33874.94) | | | (68309.95) | |
| Non-Agri. labour inc. | 23290.17 | 0 | *** | 30482.81 | 4459.40 | *** | 70689.91 | 15373.95 |
| | (81411.39) | | | (77693.01) | | | (232601.95) | |
| Transfers | 5822.49 | 0 | *** | 20107.35 | 0 | *** | 48165.57 | 1968.16 |
| | (38234.13) | | | (62634.25) | | | (180229.66) | |
| Remittances received | 8183.56 | 0 | *** | 17366.54 | 0 | *** | 44710.97 | 1668.22 |
| | (47651.97) | | | (60133.53) | | | (173041.81) | |
| Remittances from Nepal | 3707.03 | 0 | *** | 4053.82 | 0 | *** | 8154.66 | 0 |
| | (30446.39) | | | (20723.91) | | | (33189.82) | |
| Remittances from Abroad | 4476.53 | 0 | *** | 13312.71 | 0 | *** | 36556.31 | 0 |
| | (36730.44) | | | (56880.23) | | | (169939.89) | |
| Remittances sent | 1452.23 | 0 | *** | 3513.62 | 0 | *** | 37567.67 | 0 |
| | (10523.54) | | | (65777.51) | | | (1860099.7) | |
| Household size | 5.68 | 5 | *** | 5.34 | 5 | *** | 5 | 5 |
| | (2.81) | | | (2.58) | | | (2.42) | |
| Men 16-49 | 1.16 | 1 | *** | 1.04 | 1 | *** | .9 | 1 |
| | (.91) | | | (.89) | | | (.85) | |
| Women 16-49 | 1.34 | 1 | *** | 1.33 | 1 | *** | 1.3 | 1 |
| | (.85) | | | (.87) | | | (.84) | |
| Total Consumption | 90868.19 | 71424.77 | *** | 111565.98 | 83142.72 | *** | 230202.31 | 158611.13 |
| | (97864.25) | | | (119618.55) | | | (282305.69) | |
| Frequent Consumption | 72687.67 | 63506.07 | *** | 85553.99 | 70852.83 | *** | 130641.27 | 112851.66 |
| | (47155.7) | | | (61128.02) | | | (80764.13) | |
| Food cons. | 58167.04 | 50768.8 | *** | 62977.44 | 55489.61 | *** | 92560.31 | 82405.77 |
| | (37125.99) | | | (35823.89) | | | (49889.85) | |
| Work time | 4908.3 | 4248 | *** | 4794.22 | 4314 | *** | 3703.54 | 3209.5 |
| | (3369.47) | | | (2945.79) | | | (2735.41) | |
| Work time: agri. casual labour | 681.51 | 0 | *** | 441.22 | 0 | *** | 274.79 | 0 |
| | (1349.62) | | | (940.05) | | | (753.82) | |
| Work time: Non-agri. casual labour | 295.09 | 0 | *** | 279.35 | 0 | *** | 380.28 | 0 |
| | (665.52) | | | (676.29) | | | (883.05) | |
| Working time: agri. self-labour | 3339.47 | 2680 | *** | 3358.66 | 2873.5 | *** | 1956.76 | 1500 |
| | (3174.79) | | | (2698.13) | | | (1985.63) | |
| Working time: Non-agri. self-labour | 370.04 | 0 | ** | 441.67 | 0 | *** | 686.56 | 0 |
| | (1183.38) | | | (1211.06) | | | (1679.69) | |
| Working time: Permanent labour | 221.25 | 0 | ** | 273.32 | 0 | *** | 405.16 | 0 |
| | (786.36) | | | (811.96) | | | (1075.88) | |
| Observations | 2657 | | | 2748 | | | 3900 | |

Descriptive statistics for the three repeated cross-sections of NLSS in rural villages. All monetary values expressed in NPR2010

Standard errors in parentheses – $^{*} p < 0.10$, $^{**} p < 0.05$, $^{***} p < 0.01$ for difference in means between waves

Table 1.20 – Descriptive statistics: household level variables for Brahmin and Chhetry

| Variable | 1996 | | | 2003 | | | 2010 | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Median | | Mean | Median | | Mean | Median |
| Total income | 83886.40 | 60138.41 | *** | 117062.23 | 83321.44 | *** | 199137.23 | 120155.94 |
| | (94609.46) | | | (140472.58) | | | (323135.54) | |
| Agri. labour inc. | 52588.46 | 36817.43 | *** | 54619.29 | 46147.44 | *** | 59705.6 | 43800.29 |
| | (64673.21) | | | (44422.25) | | | (94323.07) | |
| Agri. self-inc. | 34055 | 22877.47 | *** | 29234.62 | 24050.36 | *** | 33581.95 | 22656.67 |
| | (42579.17) | | | (26993.97) | | | (83186.87) | |
| Non-Agri. labour inc. | 21717.98 | 0 | *** | 35976.89 | 0 | *** | 80806.33 | 6930.14 |
| | (50277.37) | | | (115813.93) | | | (264633.19) | |
| Transfers | 6806.1 | 0 | *** | 21361.66 | 0 | *** | 53112.57 | 4232.05 |
| | (30993.51) | | | (59301.02) | | | (152203.65) | |
| Remittances received | 10610.06 | 0 | *** | 19185 | 0 | *** | 47255.26 | 3157.76 |
| | (54201.61) | | | (58552.5) | | | (131676.83) | |
| Remittances from Nepal | 5636.11 | 0 | *** | 6254.94 | 0 | *** | 10757.86 | 0 |
| | (46028.86) | | | (31446.63) | | | (33073.25) | |
| Remittances from Abroad | 4973.95 | 0 | *** | 12930.06 | 0 | *** | 36497.41 | 0 |
| | (29559.15) | | | (49760.56) | | | (127986.4) | |
| Remittances sent | 1942.65 | 0 | *** | 6408.65 | 0 | *** | 100566.32 | 0 |
| | (11703.43) | | | (115407.96) | | | (3261707.29) | |
| Household size | 5.60 | 5 | *** | 5.04 | 5 | *** | 4.71 | 4 |
| | (2.56) | | | (2.07) | | | (2.16) | |
| Men 16-49 | 1.1 | 1 | *** | .98 | 1 | *** | .84 | 1 |
| | (.87) | | | (.83) | | | (.82) | |
| Women 16-49 | 1.37 | 1 | *** | 1.33 | 1 | ** | 1.25 | 1 |
| | (.86) | | | (.79) | | | (.8) | |
| Total Consumption | 99421.07 | 74045.22 | *** | 132004.78 | 95147.72 | *** | 269678.31 | 181214.66 |
| | (128634.37) | | | (167666.02) | | | (346167.25) | |
| Frequent Consumption | 74576.38 | 65370.99 | *** | 93870.16 | 78110.44 | *** | 137558.74 | 119474.64 |
| | (50644.84) | | | (68679.51) | | | (84669.01) | |
| Food cons. | 57568.18 | 49403.01 | *** | 66758.91 | 60015.89 | *** | 94858.21 | 85767.69 |
| | (39594.48) | | | (33856.54) | | | (49663.8) | |
| Working time | 5067.05 | 4320 | * | 4782.32 | 4452 | *** | 3354.4 | 2880 |
| | (3419.26) | | | (2793) | | | (2571.82) | |
| Working time: agri. casual labour | 236.91 | 0 | *** | 112.72 | 0 | ** | 79.03 | 0 |
| | (714.86) | | | (360.44) | | | (329.16) | |
| Working time: Non-agri. casual labour | 235.73 | 0 | *** | 153.37 | 0 | *** | 219.21 | 0 |
| | (596.51) | | | (462.66) | | | (595.5) | |
| Working time: agri. self-labour | 4048.03 | 3532 | ** | 3749.83 | 3330 | *** | 1928.92 | 1536 |
| | (3249.81) | | | (2559.87) | | | (1843.56) | |
| Working time: Non-agri. self-labour | 270.4 | 0 | ** | 383.03 | 0 | *** | 614.34 | 0 |
| | (971.1) | | | (1235.87) | | | (1608.86) | |
| Working time: Permanent labour | 275.47 | 0 | *** | 383.37 | 0 | *** | 512.9 | 0 |
| | (786.09) | | | (950.29) | | | (1164.46) | |
| Observations | 935 | | | 859 | | | 1268 | |

Descriptive statistics for the three repeated cross-sections of NLSS in rural villages. All monetary values expressed in NPR2010

Standard errors in parentheses – $^{\star} p < 0.10, ^{\star\star} p < 0.05, ^{\star\star\star} p < 0.01$ for difference in means between waves

Table 1.21 – Descriptive statistics: household level variables for non-high castes

| Variable | 1996 | | | 2003 | | | 2010 | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Median | | Mean | Median | | Mean | Median |
| Total income | 85214.12 | 65471.27 | *** | 99117.54 | 73145.13 | *** | 167834.43 | 109953.95 |
| | (114164.28) | | | (95075.12) | | | (301137.73) | |
| Agri. labour inc. | 54454.99 | 43669.46 | *** | 48585.51 | 39415.03 | ** | 52602.74 | 38487.62 |
| | (47838.12) | | | (44483.9) | | | (70491.69) | |
| Agri. self-inc. | 30722.2 | 20115.89 | ** | 28124.28 | 18357.86 | ** | 31930.09 | 20106.7 |
| | (38054.42) | | | (36579.7) | | | (59847.96) | |
| Non-Agri. labour inc. | 24143.82 | 2662.62 | ** | 27984.44 | 7541.69 | *** | 65816.19 | 18147.07 |
| | (94099.39) | | | (51644.01) | | | (215362.99) | |
| Transfers | 5288.42 | 0 | *** | 19536.96 | 0 | *** | 45782.29 | 1371.19 |
| | (41640.36) | | | (64099.86) | | | (192260.87) | |
| Remittances received | 6866.04 | 0 | *** | 16539.61 | 0 | *** | 43484.76 | 1236.76 |
| | (43646.89) | | | (60836.2) | | | (189796) | |
| Remittances from Nepal | 2659.59 | 0 | *** | 3052.89 | 0 | *** | 6900.06 | 0 |
| | (16663.48) | | | (13125.46) | | | (33179.24) | |
| Remittances from Abroad | 4206.44 | 0 | *** | 13486.72 | 0 | *** | 36584.7 | 0 |
| | (40096.07) | | | (59849.95) | | | (186847.39) | |
| Remittances sent | 1185.94 | 0 | ** | 2196.45 | 0 | *** | 7217.26 | 0 |
| | (9817.07) | | | (15320.12) | | | (37465.41) | |
| Household size | 5.72 | 5 | *** | 5.48 | 5 | *** | 5.14 | 5 |
| | (2.94) | | | (2.77) | | | (2.52) | |
| Men 16-49 | 1.2 | 1 | *** | 1.06 | 1 | *** | .93 | 1 |
| | (.92) | | | (.91) | | | (.86) | |
| Women 16-49 | 1.32 | 1 | *** | 1.32 | 1 | *** | 1.32 | 1 |
| | (.84) | | | (.9) | | | (.86) | |
| Total Consumption | 86224.21 | 69731.03 | *** | 102271.68 | 78394.85 | *** | 211184.24 | 149024.38 |
| | (75758.26) | | | (88129.36) | | | (243487.48) | |
| Frequent Consumption | 71662.15 | 62464.58 | *** | 81772.31 | 67200.78 | *** | 127308.69 | 109671.23 |
| | (45130.56) | | | (56985.7) | | | (78613.36) | |
| Food cons. | 58492.2 | 51564.51 | ** | 61257.87 | 53720.02 | *** | 91453.26 | 80052.23 |
| | (35721.97) | | | (36563.16) | | | (49970.08) | |
| Working time | 4822.1 | 4165 | ** | 4799.63 | 4244 | *** | 3871.75 | 3360 |
| | (3339.96) | | | (3013.41) | | | (2795.78) | |
| Working time: agri. casual labour | 922.92 | 0 | *** | 590.6 | 0 | *** | 369.1 | 0 |
| | (1538.84) | | | (1074.85) | | | (873.25) | |
| Working time: Non-agri. casual labour | 327.32 | 0 | *** | 336.63 | 0 | *** | 457.87 | 0 |
| | (698.20) | | | (746.77) | | | (983) | |
| Working time: agri. self-labour | 2954.75 | 2270 | ** | 3180.78 | 2640 | *** | 1970.18 | 1500 |
| | (3066.38) | | | (2740.95) | | | (2050.78) | |
| Working time: Non-agri. self-labour | 424.13 | 0 | ** | 468.33 | 0 | *** | 721.35 | 0 |
| | (1281.06) | | | (1198.99) | | | (1711.98) | |
| Working time: Permanent labour | 191.81 | 0 | ** | 223.28 | 0 | *** | 353.25 | 0 |
| | (785.17) | | | (735.42) | | | (1026.7) | |
| Observations | 1722 | | | 1889 | | | 2632 | |

Descriptive statistics for the three repeated cross-sections of NLSS in rural villages. All monetary values expressed in NPR2010

Standard errors in parentheses – $^{*} p < 0.10$, $^{**} p < 0.05$, $^{***} p < 0.01$ for difference in means between waves

Table 1.22 – Descriptive statistics: village level variables

| Variable | 1996 Mean | 1996 Median | | 2003 Mean | 2003 Median | | 2010 Mean | 2010 Median |
|---|---|---|---|---|---|---|---|---|
| $Killings_{20km}^{[t-6;t-1]}$ | .04 | 0 | *** | 12.03 | 8 | *** | 0 | 0 |
| | (.25) | | | (12.72) | | | (0) | |
| $Killings_{20km}^{[t-6;t+5]}$ | .23 | 0 | *** | 30.28 | 25 | *** | 0 | 0 |
| | (1.12) | | | (21.82) | | | (0) | |
| $Killings_{20km}^{[onset;t-7]}$ | .07 | 0 | *** | 58.82 | 43 | *** | 146.22 | 129 |
| | (.25) | | | (59.97) | | | (85.68) | |
| Wood price (USD) | 69.59 | 62.98 | *** | 200.27 | 230.25 | *** | 289.25 | 333.35 |
| | (23.85) | | | (67.97) | | | (87.32) | |
| Distance to India (km) | 49.98 | 50.77 | *** | 47.53 | 45.06 | *** | 46.72 | 43.33 |
| | (37.03) | | | (37.07) | | | (35.19) | |
| NDVI$\times$ 100 | | | *** | 82.68 | 84.16 | *** | 83.04 | 83.75 |
| | | | | (6.55) | | | (6.01) | |
| Rain anomalies (z-score) | | | *** | .46 | .55 | *** | -.74 | -.77 |
| | | | | (.69) | | | (.72) | |
| Observations | 215 | | | 229 | | | 325 | |

Descriptive statistics for the three repeated cross-sections of NLSS in rural villages. All monetary values expressed in NPR2010
Standard deviation in parentheses – $^{\star}p < 0.10, ^{\star\star} p < 0.05, ^{\star\star\star} p < 0.01$ for difference in means between waves

Chapter 2

# Firewood Collections, Forest Conditions and Economic Growth: Evidence from Rural Nepal in 2003-2010

**Jean-Marie Baland, François Libois and Dilip Mookherjee**

## Abstract [1]

A combination of satellite imagery with household cross-sectional and panel data set is used to investigate the effects of economic growth on firewood collection in Nepal between 2003 and 2010, and their implications for the evolution of the forests. We first find that (a) increased firewood collections are associated with rising consumption levels, contrary to the Poverty-Environment hypothesis; but (b) the nature of the growth process matters, as a switch away from farm based activities reduces collections substantially. More abundant forest biomass and lower collection times both increase collections, but the effects are relatively small. Conversely, collections represent at most 0.5% of the available forest biomass, and therefore do not as such pose a major problem. Forest biomass has indeed remained essentially stable over the last decade in the region. Finally, the presence of Forest User Groups, the village-based forest management decentralization scheme in Nepal, are associated with lower collections, longer collection times and larger expenditures on alternative fuels.



*Keywords:*

Deforestation ; Growth ; Environmental Kuznets Curve ; Nepal

*JEL Classification*:

O1, D12, Q2



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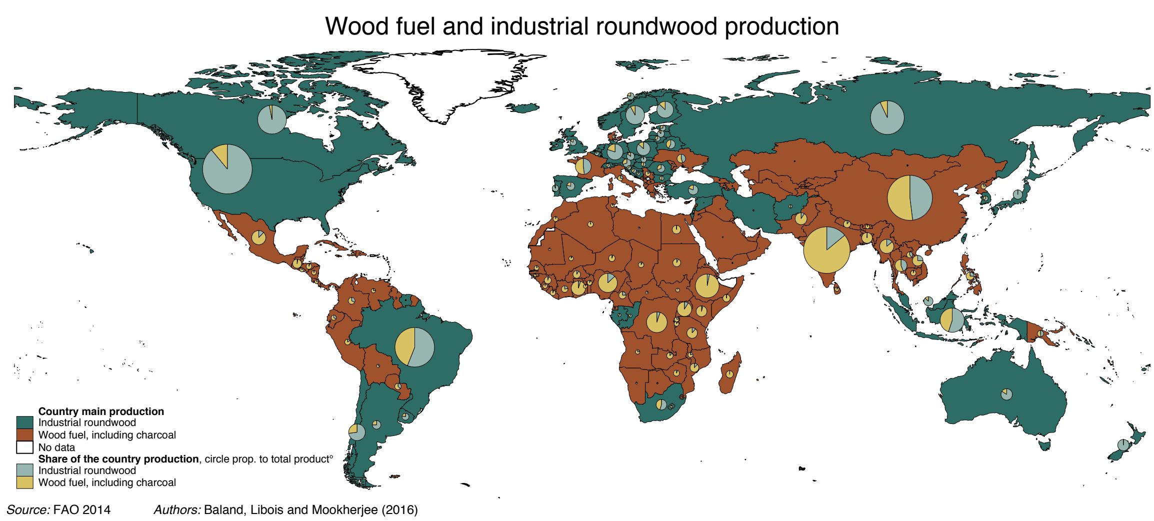
## 2.1 Introduction

Deforestation in South Asia and Sub-Saharan Africa poses serious developmental and ecological problems. Large sections of neighbouring populations of developing countries rely on forests for household fuel, timber and fodder, and spend a large amount of time collecting these products. The ecological problems pertain to increased soil erosion, water salinity, siltation in rivers, and increased likelihood of landslides and floods which affect large non-neighbouring populations adversely [2]. In these countries, wood fuel extraction is the main driver of biomass removal. Figure 2.1 shows that almost all African and Asian countries mostly extract wood fuel from their forest, and notably the main producer of wood like India, China, Democratic Rebublic of Congo, Ethiopia or Nigeria. Industrial roundwood production is sizeable only in a very limited set of developing countries including Brazil, Gabon, China, Indonesia and Malaysia. It is therefore crucial to understand the relation between household demand for fuel and forest degradation.

Figure 2.1 – Extraction of forest products in the world




2. For detailed references concerning these problems, see Arrow et al. (1995), Dasgupta and Mäler (1995), Dasgupta et al. (2000) and various references cited in Baland et al. (2010b)

In this paper, we investigate the interactions between economic growth, firewood collections and deforestation in the context of the Hills and the Mountains of rural Nepal over the last decade [3]. To this end, we use the two large scale household surveys organized by the Central Bureau of Statistics of Nepal in collaboration with the World Bank in 2003 and 2010, which also contain a limited but representative household panel. We combine this data set with various measures of forest biomass based on satellite imagery, which we reconstructed at the village level over different periods. We focus on firewood collection for two reasons. First, it represents by and large the main driver of forest degradation in the Himalayas compared to encroachment or timber collection (see e.g. (Baland et al., 2014, pp.209-210)). Second it is the only information available at the household level. Nepal is an appropriate context to study since it has been subject to serious deforestation in the last century, with forest cover declining at an estimated annual rate of 1.9% over the 1980s and the 1990s (UNEP, 2011).

At the household level, we first explore firewood collections, which fell by 8% over this period while living standards, as measured by consumption expenditures, increased by 59%. These changes can be rationalized in a number of ways. Some scholars indeed argue that poverty is the major factor that drives households to rely on forest firewood rather than modern fuels; hence declining poverty made possible by economic growth will reduce the pressure on forests. This view, commonly referred to as the Poverty-Environment hypothesis (PEH), is apparently compatible with the changes described above [4]. These changes can also be *'explained'* as the declining part of the Environmental Kuznets Curve (EKC), which states environmental degradation will intensify with growth in living standards until a threshold, beyond which it will fall [5]. By contrast, another common view, expressed by the World Bank as well as the 2006 World Economic Forum Summit, believes that income growth will increase the demand for household energy, thereby putting additional pressure on forests (the principal source of household fuel). This view does not seem to support the observed changes [6].

3. We therefore exclude the low-level Terai regions as they are subject to completely different agro-climatic and ecological conditions.
4. Barbier et al. (1997); Barbier (1998, 2010); Duraiappah (1998); Jalal (1993); Lele (1991); Lopez (1998); Maler (1998)
5. Barbier (1997); Grossman and Krueger (1995); Yandle et al. (2002)
6. World Economic Forum 2006 Summit Report, Word Bank (2000)

The differences between these hypotheses stem from alternative assumptions regarding the nature of wealth effects (i.e., whether firewood is a normal or an inferior good) and their strength relative to substitution effects. We estimate Engel curves and find that, contrary to the observed average changes, collections are essentially rising with consumption levels. Hence growth in living standards *per se* tends to accelerate the pressure on the forest for the vast majority of the population, which goes against the PEH. This result is robust to functional forms, the use of cross-sectional or panel data and a large range of household and village attributes. These Engel curves however fail to capture the overall trends described above.

Given the identification problems, we then propose a reduced form approach and find that the observed fall in collections is explained by a substantial shift away from farm based traditional assets, and the corresponding changes in occupational patterns. While a key question frequently debated by scholars [7], media [8] and policy-making community [9] concerns the likely effect of economic growth on environmental degradation in these countries, we therefore find that it is not growth itself but the nature of the growth process that matters. These findings are consistent with the trends followed by household expenditures on alternative fuels [10].

We then investigate the relation between fuelwood collections and the local forest conditions at the village level, using the forest biomass data we collected. First, we find that forest biomass has been essentially stable over the last decade, contrary to the declining trends observed in the literature for the preceding decades. We also find that collection times are sensitive to local forest conditions, but the effects are not large. Collections are also sensitive to both local forest biomass and collection times, but the effects there are also relatively small. Thus, a doubling in collection time results in an average fall of at most 20% in the amounts collected. We then investigate the impact of firewood collections on forest biomass. We first find that total collections have not changed over the last decade in spite of the fall in individual collections because population density has increased in the villages. Moreover, total firewood collections account for at most 2% of the forest biomass, which does not

7. Arrow et al. (1995); Dasgupta et al. (2000)
8. *The Economist*, July 8 2004; *The Economist*, September 23 2010
9. For instance, the World Bank report on deforestation in India stated: *"urbanization, industrialization and income growth are putting a tremendous demand pressure on forests for products and services. The shrinking common property resource base, the rapidly increasing human and livestock population, and poverty are all responsible for the tremendous degradation pressure on the existing forest cover"* (Word Bank, 2000, Summary section, page xx)
10. Amacher et al. (1996); Baland and Platteau (1996); Baland et al. (2010b); Bluffstone (1995)

exceed the natural regeneration rate. Finally, we find that the presence of a Forest User Group (FUG) is associated with longer collection times and lower collection levels. Collection activities are also not directly affected by the regional differences in the intensity of the civil war in Nepal during this period, nor by the out-migration of household members.

Despite the importance of the issue, there are very few explicit attempts in the literature at analysing the relationship between economic growth, fuel choices and forests conditions at a micro-economic level. Moreover, given the scarcity of longitudinal data sets, nearly all studies are based on cross-sectional data, comparing firewood collection behaviour between different households with varying incomes at a single point of time. While our evidence is essentially based on cross-sectional data, we will also partly rely on a household panel which corrects for the possibility of unobserved heterogeneity between households and local communities. More importantly, forest conditions are often measured through imperfect proxies, such as the time taken to collect firewood at the time of the survey. The recent availability of high definition satellite imagery allows for a much more precise assessment of forest conditions, and their relation with collection times. Moreover, their systematic measurement over time also allows to investigate the impact of human activities such as fuelwood collections on the evolution of the forests. With the exception of Foster and Rosenzweig (2003), we are not aware of any study analysing the changes in forest biomass and relating these to local energy use based on a household survey.

The paper is organized as follows. In Section 2, we describe the major trends in the collection of firewood in Nepal between 2003 and 2010. We then present Engel curves and their reduced form counterparts in Section 3. In section 4, we examine more closely the effects of forest biomass on collections and collection time. We also investigate how changes in biomass are themselves related to the aggregate firewood collection at the village level. Section 5 discusses the existing literature and concludes the paper.

## 2.2 Data and descriptive statistics

The World Bank Living Standards Measurement Survey (LSMS) for Nepal interviewed 3912 households concerning their production and consumption activities for the year 2002-3 and 5988 in 2010-11 [11]. We focus on the villages located in the Hills and Mountains of Nepal, which share a similar agro-ecological system and a comparable reliance on forest resources, and therefore have a total sample of 3590 households (1474 in 2003 and 2116 in 2010), located in 301 villages. A random subset of these households was selected by the World Bank to constitute a moving panel representative of Nepal. Our panel data covers 382 different households in 40 villages. Tables 2.9 - 2.11 in the Appendix provides a description of the main household level variables used in our analysis.

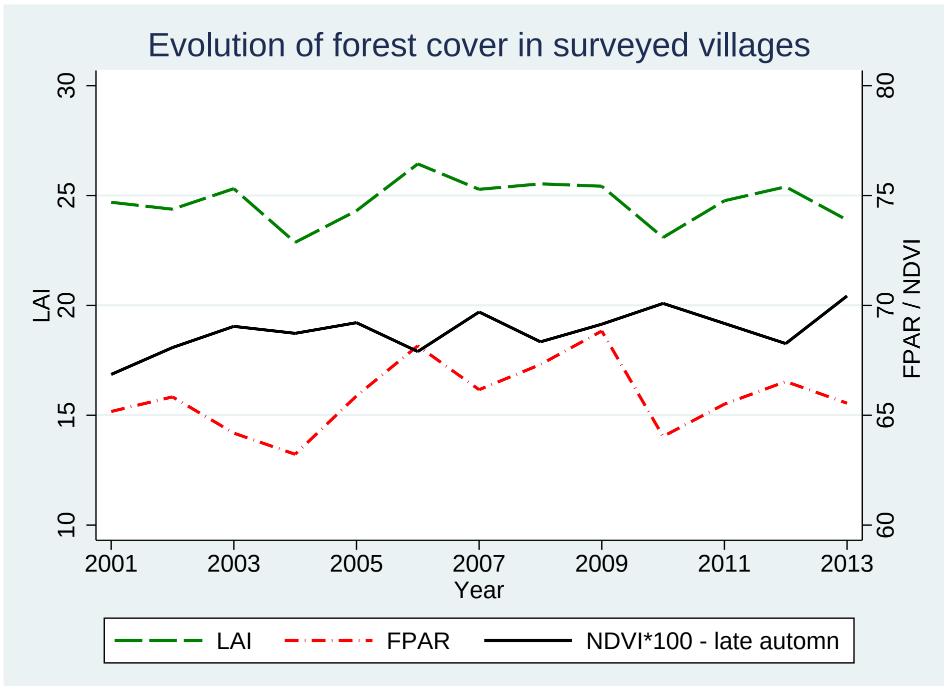
In this region, almost all households collect and consume firewood, which is the primary source of cooking fuel and heating source. The quantities of firewood exchanged on the market are negligible. Each household collects on average 81.75 bharis of firewood (headloads corresponding to about 30 kg of wood), and spends 3.75 hours to collect one such bhari. Between 2003 and 2010, the amount of firewood collected fell by 8%, while collection time increased by about 12%. Overall, fuel expenditures (that exclude firewood collected) amount to 2,086 NPR (from 1,379 NPR in 2003 to 2,578 NPR in 2010), which represents 2% of all expenditures.

Household living standards (measured by value of annual consumption at 2010 prices) were equal on average to 101,000 NPR, and increased substantially (by about 60%) during this period. This change is related to the sharp increase in remittances received from migrants, with a rise in the mean number of migrant per household from 0.4 in 2003 to 0.8 in 2010. Remittances account for one-third of household income by 2010. On average, households are mostly engaged in farming as they spend on average 76% of their time in agricultural occupations. This dependence on farming decreased substantially, as the proportion of time spent on agricultural activities fell from 0.82 to 0.72 between 2003 and 2010. Changes in the structure of productive assets owned by the households reflect this evolution. Thus, between 2003 and 2010, the number of livestock heads fell from 3.53 to 3.15, the amount of land owned from 0.68 to 0.61 hectares and household size from 5.02 to 4.79 individuals. By contrast, the average adult education increased from 2.41 to 3.16 years of schooling and the proportion of households owning non-farm business assets, from 0.22 to 0.28.

11. Note that the 2002-3 LSMS was effectively administered in 2003 and part of 2004. To avoid confusion, we refer to the year of that particular survey as 2003, and to the other as 2010. Another Nepal LSMS was also administered in 1995 and has been analyzed in Baland et al. (2010b). Unfortunately, the satellite imagery data available in the 90s do not provide the relevant information necessary for our research. We have therefore decided to drop this additional dataset, and instead check the consistency of our new findings, with those already highlighted in this previous paper.

We measure forest biomass in a village by three different approaches. All remote-sensing measures suffer from non-trivial measurement errors observed at the micro-level, which justifies the use of alternative approaches (see e.g. Glenn et al. (2008)). All these measures have been averaged over the village territory, using administrative boundaries of the survey villages to identify the relevant pixels [12].

Figure 2.2 – Evolution of biomass in surveyed villages in the 2000's




We first rely on the leaf area index, LAI, which corresponds to the share of an area which is covered by leaves, and is therefore closely related to the more traditional measure of crown cover, but in a finer way as it takes into account the differences between pine and broadleaved trees. Given the seasonality in the density of leaves in those areas, we use the 90 percentile of the measure in a year (we avoided using the maximum as the latter is more subject to measurement errors). Our central estimations are based on this particular measure. We also employ the fraction of absorbed photosynthetically active radiation, FPAR, which measures the photosynthesis capacity of standing vegetation. It is a key parameter to understand the

12. LAI and FPAR pixels have a $1km \times 1km$ resolution while NDVI is more precise with a $250m \times 250m$ resolution

growth potential and carbon storage capacity of the biomass. There again, because of seasonality, we will use the 90 percentile [13]. Finally, we will also make use of the more traditional Normalized Difference Vegetation Index (NDVI), for which we computed the village wise average of the November-December maximum of each pixel. This methodology follows the bimonthly production algorithm which report for every 16 days the maximum of the ratio $\frac{\text{Near Infra Red} - \text{Visible Red}}{\text{Near Infra Red} + \text{Visible Red}}$. It proxies the amount of radiation captured by chloroplast, which are green because they absorb all visible colours but green. The closer to one the ratio is, the denser is the vegetation cover of the pixel. We focus on November and December to limit the greening of pixels due to agricultural standing crops and capture as much as possible the canopy [14]. These three measures vary a lot across villages, but remain remarkably stable between 2003 and 2010. In Figure 2.2 above, we report for the villages surveyed in the Nepal LSMS the evolution of our three measures of biomass between 2001 and 2013. While there is some fluctuations between years, there are no discernible trends in any of those measures, except perhaps a slight increase in NDVI over the decade.

The Forest User Group program was launched in 1993. Its objective has been to transfer the management of accessible forests to local communities, via Community Forest User Groups (CFUGs). These groups are empowered to control access to the forests, taxing forest products, hiring forest guards and launching plantation programme [15]. Income generated by forest-related activities can be used to finance local projects such as roads, schools and temple. Most of the villages have at least one forest user group (87% in 2003 and 95% in 2010) and the area controlled by CFUGs increased substantially over the period, from 14% to 20% of the total village area.

Another important event during the study period was the Nepalese Civil War between government forces and Maoist rebels, which started in 1996 and ended in 2006. The civil war culminated in 2003 and 2004 with the Maoist rebels controlling a large part of the countryside. In this paper, we use the INSEC dataset which provides the most reliable data source on conflict intensity, reporting the number of

13. Alternatively, we will also use as robustness checks the average of these measures in the early winter season, during which most standing crops have been collected, and trees are still fully covered by leaves. More technical details and sources about these measures are provided in Appendix A1. For more details on LAI and FPAR products using MODIS data, see also Myneni et al. (2002).

14. For more details on NDVI products using MODIS data, see Solano et al. (2010)

15. Certain legal restrictions are set for the use of these funds. For example, 25% of revenue must be reinvested in projects aimed at developing the forest.

conflict related casualties, with the date of the event and its geo-localization. Using the centroid of each village in our data set, we computed the total number of conflict related deaths since the start of the conflict within a 20 km radius around the center of the village [16]

Last, we systematically control for environmental and climatic conditions using remote sensing information. Snow cover and cooling degree days (CDD) determine the demand for firewood. Growing Degree Days are computed for each monsoon season to capture one of the important determinant of biomass growth over the year. We also control for rainfall z-score, the village median altitude and within village altitude variance. The appendix describes data sources and computational details for these variables.

## 2.3 Firewood collection and living standards

In this section we focus on the relationship between household consumption and firewood collections, in order to test commonly held views such as PEH or EKC concerning the effect of growth in living standards on firewood collections. Conceptually this corresponds to estimating the nature of the income effect in the demand for firewood, and therefore requires to control for collection time, which is the main cost (price) associated with the consumption of firewood. We first provide cross-sectional estimates of this relation. Controlling for village dummies and focusing on intra-village variations in a cross-sectional analysis helps control for the bias resulting from unobserved village heterogeneity, but does not allow to estimate the effects of collection times, which is constant in a village. The estimation based on the panel enables us to additionally gauge the bias resulting from unobserved household heterogeneity that is fixed over time, besides changes in observable household attributes. This comes however at a cost, due to the lower number of households, and also to the reduced variability across time of most of the variables of interest. Unless otherwise specified, in all the other estimations, we will use belt-zones dummies to control for regional characteristics. A belt zone is defined administratively as a region of

16. More details on this variable are available in Libois (2016). According to Do and Iyer (2010), the Nepal civil war was concentrated in geographic locations favoring insurgents, such as mountains and forests, and in areas of greater poverty owing to the need of the insurgents to recruit soldiers (see also Bohara et al. (2006) and Hatlebakk (2010). As a result, we are not able to draw reliable estimates of the effects of the civil war on firewood collections, and our estimations results in this respect are disappointing.

roughly similar geographical characteristics (usually, low plains, hills and mountains correspond to three different 'belts'). We distinguish between 22 belt zones in the Hills and the Mountains, which include on average 2.5 districts or 13.7 villages. The use of belt zones allows for more variability across villages, but the results are robust to the use of district fixed effects, with some loss in significance.

Table 2.1 presents estimated Engel relationships using alternative parametric specifications and with varying sets of controls. Consumption is measured by annual household recurrent expenditures valued at 2010 prices. The first three columns show estimated relationships from the cross-sectional data (which pools the two waves) using a quadratic specification [17]. In the first column, we control for village and time dummies, in the second column, we control for a belt-zone dummy, and for the median collection time in the village (which was absorbed by the village dummy in column 1) [18]. In column 3, we add other village level controls, including the share of forest managed by Forest User Group, the distance to a paved road, the number of conflicts related deaths within 20 km of the village, and various topographic and climatic controls. Columns 4-6 present the corresponding panel estimates, with column 4 including a time-varying village fixed effect, column 5 and 6 including a different set of village time-varying controls. Standard errors are clustered at the village level in all regressions. Column 7 is a semi-parametric estimation on the panel that we discuss later.

All columns show a significant increasing and concave relationship between firewood collections and consumption. The estimated turning point are located at least at 200,000NPR, corresponding to consumptions above the 93th percentile. The evidence therefore firmly rejects the PEH but is consistent with the EKC. These patterns do not however explain the observed changes in collections and consumption between 2003 and 2011.

17. Higher order polynomials were also tested, with little impact on the estimates. We report on a semi-parametric specification below. While not reported here, all the results discussed are robust to using income instead of consumption expenditures as the measure of income.
18. The use of individual self-reported collection time per bhari, while arguably more endogenous, does not affect our conclusions.

Table 2.1 – Engel curves

| | (1) Wood | (2) Wood | (3) Wood | (4) Wood | (5) Wood | (6) Wood | (7) Wood |
|---|---|---|---|---|---|---|---|
| Consumption exp. | 0.372*** | 0.246*** | 0.274*** | 0.852*** | 0.888*** | 0.926*** | |
| | (8.03) | (5.23) | (6.13) | (4.03) | (4.20) | (4.39) | |
| Consumption exp.$^2$ | -0.000539*** | -0.000429*** | -0.000455*** | -0.00200*** | -0.00220*** | -0.00225*** | |
| | (-4.37) | (-4.46) | (-4.58) | (-3.49) | (-3.84) | (-3.83) | |
| Med. collection time | | -3.123* | -3.959** | | -1.577 | -0.702 | 0.0935 |
| | | (-1.96) | (-2.41) | | (-0.40) | (-0.16) | (0.03) |
| % of Vil. area in FUG | | | -15.74 | | | 112.6 | 123.0 |
| | | | (-1.20) | | | (1.27) | (1.41) |
| Med. time to road | | | -0.233 | | | -1.838** | -1.436* |
| | | | (-0.91) | | | (-2.16) | (-1.77) |
| # killings 20km ar. | | | -0.00607 | | | 0.0111 | -0.00818 |
| | | | (-0.22) | | | (0.09) | (-0.08) |
| Vil. elevation: mean | | | -0.00777 | | | | |
| | | | (-1.07) | | | | |
| Vil. elevation: std. dev. | | | 0.0553*** | | | | |
| | | | (3.06) | | | | |
| Vil. snow cover | | | -287.0 | | | 7096.9*** | 6951.7*** |
| | | | (-0.26) | | | (3.03) | (3.13) |
| Rainfall z-score | | | -2.376 | | | 3.436 | 4.499 |
| | | | (-0.80) | | | (0.52) | (0.92) |
| Monsoon GDD | | | -0.0189 | | | -0.0413 | -0.0445 |
| | | | (-1.61) | | | (-1.00) | (-1.34) |
| Cooling Degree Days | | | -0.00967 | | | -0.102** | -0.112** |
| | | | (-0.52) | | | (-2.65) | (-2.44) |
| Year fixed-effects | Yes | Yes | Yes | YES | Yes | Yes | Yes |
| Other fixed-effects | Village | Belt-Zone | Belt-Zone | Household | Household | Household | Household |
| Other fixed-effects | | | | Village-year | | | |
| Observations | 4446 | 4446 | 4446 | 764 | 764 | 764 | 764 |
| Est. turning point | 344.93 | 286.38 | 301.22 | 212.56 | 201.58 | 205.68 | |

Standard errors clustered at the village level, $t$-statistics in parentheses, $^{*}p < 0.1,^{**} p < 0.05,^{***} p < 0.01$

The effects of collection time is significant in the cross-section, but not in the panel, due essentially to the low variability of this variable within a village. Where significant, the estimated effect remains small, as one more hour needed to collect one bhari (a 27% increase) is associated with a fall of at most 4 bharis collected, which corresponds to an average elasticity of about -15%.

We next explore the robustness of the results with respect to functional form of the relationship between collections and consumption. Figure 2.3 provides the semi-parametric estimations of the Engel curve on the household panel, relating changes in household firewood collection to the changes in household consumption expenditures within the same household. To estimate this curve, we use the estimator proposed by Baltagi and Li (2002) which allows consistent estimates in a semi-parametric panel regression [19]. The estimation controls for household fixed effect and the village variables (such as conflict intensity or the presence of a FUG), the coefficients of which are reported in column 7 of Table 2.1. We again find an increasing and concave relation between firewood collections and consumption, which closely follow a quadratic shape. The right hand panel of Figure 2.3 reports the distribution of consumption across all households.

In a rural setting where households collect their own firewood and spend large amounts of time doing so, it is hard to dispute the possibility that household consumption and firewood collections are jointly determined by labour allocation decisions and other underlying household and community attributes. Observable household attributes include household demographics, occupational patterns and assets owned. The likely influence of these attributes motivates a reduced form analysis in which collections are related to underlying household assets rather than consumptions. An added argument for such an approach is that household consumptions are more prone to measurement error than household assets.

19. Baltagi and Li (2002) suggest eliminating the fixed-effects by first differencing the model over time, assuming that the non-parametric part of the regression has the same functional form in both periods. Combined with the use of sufficiently flexible splines, this assumption allows estimating consistent parameters which will be used to partial out the non-parametric part of the model from its parametric components. The partialled-out residuals will then be used to draw the non-parametric part of the regression. For more details, see Libois and Verardi (2013).

Figure 2.3 – Firewood demand: Engel curve

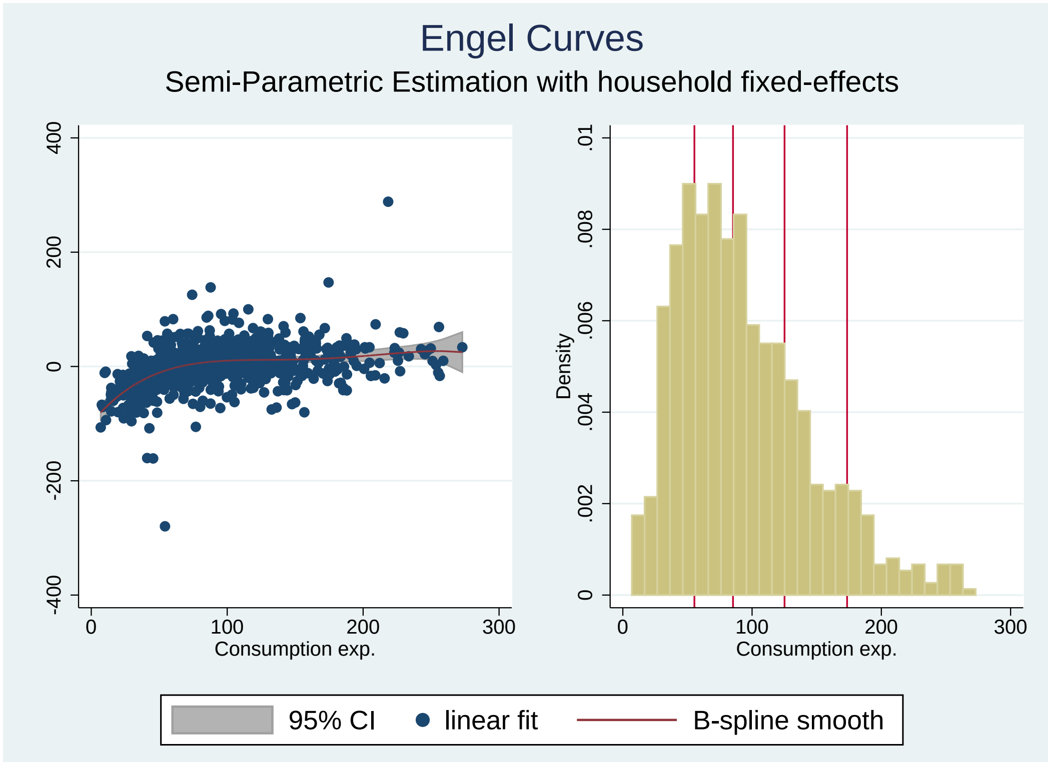



Table 2.2 reports the regression estimations of consumption expenditures and the proportion of adult worktime allocated to agriculture on household assets and demographics. Columns 1 and 3 include a village fixed effect, while various village level controls are included in the two other columns. Clearly, living standards and occupational patterns are closely related to all productive assets in the expected way. These regressions have a within-R-squared varying between 27 and 33%. Changes in assets and demographics therefore account for some but not most of the observed growth in consumptions. This implies that while the results of an asset-based reduced form approach is less prone to estimation bias, it is not able to incorporate all the factors generating growth in living standards. Hence the reduced-form asset-based approach and the Engel curve approaches are complementary.

In Table 2.3, we investigate the reduced form approach, in which collections are related to household demographics and assets. As a first step, we reproduce the

Table 2.2 – Consumption and occupational patterns: determinants

| | Frequent consumption | | Prop. agricultural worktime | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Big livestock | 1.660$^{***}$ | 0.571 | 0.0181$^{***}$ | 0.0222$^{***}$ |
| | (3.63) | (1.26) | (7.60) | (9.01) |
| Land owned, ha | 14.70$^{***}$ | 12.87$^{***}$ | 0.0107 | 0.0265$^{***}$ |
| | (8.40) | (7.79) | (1.54) | (3.58) |
| Household size | 9.887$^{***}$ | 9.923$^{***}$ | -0.0126$^{***}$ | -0.0126$^{***}$ |
| | (14.04) | (14.01) | (-4.96) | (-5.11) |
| Prop. children | -13.39$^{***}$ | -18.45$^{***}$ | 0.0294 | 0.0592$^{***}$ |
| | (-3.25) | (-4.23) | (1.33) | (2.77) |
| Avg. education | 4.991$^{***}$ | 6.510$^{***}$ | -0.0186$^{***}$ | -0.0243$^{***}$ |
| | (12.65) | (13.30) | (-8.45) | (-11.04) |
| = 1 if NFBus | 9.922$^{***}$ | 10.62$^{***}$ | -0.255$^{***}$ | -0.268$^{***}$ |
| | (4.37) | (4.45) | (-17.40) | (-19.91) |
| # Migrants | -0.00755 | -0.0320 | 0.0499$^{***}$ | 0.0460$^{***}$ |
| | (-0.01) | (-0.03) | (8.89) | (8.57) |
| % of Vil. area in FUG | | 13.79 | | -0.0481 |
| | | (1.62) | | (-1.11) |
| Med. time to road | | 0.149 | | 0.00142$^{*}$ |
| | | (1.08) | | (1.91) |
| # killings 20km ar. | | 0.0357$^{**}$ | | 0.0000346 |
| | | (2.26) | | (0.45) |
| Vil. snow cover | | -1027.7 | | -7.583$^{**}$ |
| | | (-1.43) | | (-2.12) |
| Rainfall z-score | | 1.235 | | 0.00841 |
| | | (0.58) | | (0.84) |
| Monsoon GDD | | 0.00196 | | 0.00000354 |
| | | (0.40) | | (0.16) |
| Cooling Degree Days | | 0.0179 | | 0.0000979$^{*}$ |
| | | (1.57) | | (1.66) |
| Year F.E. | Yes | Yes | Yes | Yes |
| Belt-Zone F.E. | Yes | Yes | Yes | Yes |
| Village F.E. | Yes | No | Yes | No |
| Observations | 3590 | 3590 | 3590 | 3590 |

Standard errors clustered at the village level
$t$-statistics in parentheses, $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

estimated Engel curve, controlling for the proportion of adult productive time in the household allocated to agricultural activities. The intuition here is that farming activities, such as fodder collection or livestock grazing, are complementary to firewood collection while others are not. Columns 1-3 reproduce the first three columns of table 1, with the proportion of agricultural worktime as an additional control. The estimated coefficients on consumption and collection time closely parallel those obtained in Table 1, with a similar interpretation. Occupational patterns also matter: a complete switch by a household away from agriculture would result in a fall in firewood collection by at least 16 bharis (col. 1).

The estimated reduced form approach is presented in columns 4-6, where consumption expenditures and occupational patterns are replaced by household assets. As expected, farm based assets (livestock and agricultural land) and household size increase collections, as the effect of income and occupation complement each other. With respect to household size, we also expect an additional positive effect as energy use, particularly in terms of heating, is essentially a public good within the household. In contrast, the occupational effects dominate the income effect for the impact of education and non-farm business asset ownership which both decrease collections.

Table 2.3 – Engel curves and occupational pattern

| | (1)<br>Wood | (2)<br>Wood | (3)<br>Wood | (4)<br>Wood | (5)<br>Wood | (6)<br>Wood |
|---|---|---|---|---|---|---|
| Consumption exp. | 0.391*** | 0.291*** | 0.304*** | | | |
| | (8.40) | (6.49) | (6.81) | | | |
| Consumption exp.$^2$ | -0.000560*** | -0.000464*** | -0.000484*** | | | |
| | (-4.52) | (-4.81) | (-4.90) | | | |
| Prop. agri. worktime | 15.99*** | 31.17*** | 30.48*** | | | |
| | (4.37) | (7.31) | (7.22) | | | |
| Med. collection time | | -3.219** | -3.322** | | -3.411** | -3.562** |
| | | (-2.16) | (-2.21) | | (-2.52) | (-2.56) |
| % of Vil. area in FUG | | | -17.02 | | | -11.05 |
| | | | (-1.41) | | | (-1.00) |
| Med. time to road | | | -0.224 | | | -0.217 |
| | | | (-0.87) | | | (-0.94) |
| # killings 20km ar. | | | -0.0182 | | | 0.00644 |
| | | | (-0.68) | | | (0.27) |
| Vil. snow cover | | | 303.1 | | | 69.15 |
| | | | (0.28) | | | (0.07) |
| Rainfall z-score | | | -1.993 | | | -0.556 |
| | | | (-0.69) | | | (-0.20) |
| Monsoon GDD | | | -0.0200*** | | | -0.0179*** |
| | | | (-2.78) | | | (-2.67) |
| Cooling Degree Days | | | -0.0106 | | | -0.00617 |
| | | | (-0.59) | | | (-0.36) |
| Big livestock | | | | 2.450*** | 2.979*** | 2.838*** |
| | | | | (4.61) | (5.51) | (5.24) |
| Land owned, ha | | | | 1.719 | 4.457** | 4.052** |
| | | | | (0.91) | (2.41) | (2.15) |
| Household size | | | | 6.390*** | 6.369*** | 6.547*** |
| | | | | (11.03) | (10.70) | (11.05) |
| Prop. children | | | | -5.105 | -2.197 | -3.071 |
| | | | | (-1.12) | (-0.47) | (-0.66) |
| Avg. education | | | | -0.789** | -2.348*** | -2.217*** |
| | | | | (-2.02) | (-6.15) | (-5.84) |
| = 1 if NFBus | | | | -4.378** | -6.258*** | -6.391*** |
| | | | | (-2.10) | (-2.81) | (-2.85) |
| # Migrants | | | | 1.571 | -1.141 | -1.039 |
| | | | | (1.60) | (-1.08) | (-1.00) |
| Year F.E. | Yes | Yes | Yes | Yes | Yes | Yes |
| Belt-Zone F.E. | Yes | Yes | Yes | Yes | Yes | Yes |
| Village F.E. | Yes | No | No | Yes | No | No |
| Observations | 3590 | 3590 | 3590 | 3590 | 3590 | 3590 |

Standard errors clustered at the village level, $t$-statistics in parentheses, $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 2.4 – Engel curves and occupational pattern: fuel expenditures

| | (1) Fuel exp. | (2) Fuel exp. | (3) Fuel exp. | (4) Fuel exp. | (5) Fuel exp. | (6) Fuel exp. | (7) Fuel exp. | (8) Fuel exp. | (9) Fuel exp. |
|---|---|---|---|---|---|---|---|---|---|
| Consumption exp. | $11.61^{*}$ | $14.66^{**}$ | $13.93^{**}$ | $10.23^{*}$ | $12.05^{*}$ | $11.65^{*}$ | | | |
| | (1.92) | (2.35) | (2.20) | (1.71) | (1.95) | (1.85) | | | |
| Consumption exp.$^2$ | 0.0104 | 0.00966 | 0.00967 | 0.0119 | 0.0117 | 0.0115 | | | |
| | (0.51) | (0.45) | (0.45) | (0.59) | (0.56) | (0.54) | | | |
| Prop. agri. worktime | | | | $-1126.2^{***}$ | $-1804.0^{***}$ | $-1672.3^{***}$ | | | |
| | | | | (-4.36) | (-4.99) | (-5.07) | | | |
| Med. collection time | | $376.2^{**}$ | $356.9^{**}$ | | $381.8^{**}$ | $357.2^{***}$ | | $378.0^{***}$ | $353.3^{***}$ |
| | | (2.50) | (2.55) | | (2.58) | (2.60) | | (2.60) | (2.60) |
| Big livestock | | | | | | | $-64.78^{*}$ | $-164.6^{***}$ | $-135.5^{***}$ |
| | | | | | | | (-1.88) | (-3.63) | (-3.16) |
| Land owned, ha | | | | | | | 101.6 | -75.95 | -113.9 |
| | | | | | | | (1.07) | (-0.76) | (-1.12) |
| Household size | | | | | | | $104.3^{**}$ | $133.8^{***}$ | $133.5^{***}$ |
| | | | | | | | (2.38) | (2.79) | (2.77) |
| Prop. children | | | | | | | -67.10 | -524.1 | -496.7 |
| | | | | | | | (-0.21) | (-1.51) | (-1.43) |
| Avg. education | | | | | | | $155.1^{***}$ | $226.2^{***}$ | $222.3^{***}$ |
| | | | | | | | (5.49) | (6.14) | (6.53) |
| = 1 if NFBus | | | | | | | $418.8^{***}$ | $466.7^{***}$ | $415.5^{**}$ |
| | | | | | | | (2.69) | (2.76) | (2.48) |
| # Migrants | | | | | | | -37.64 | $-166.8^{**}$ | $-154.7^{**}$ |
| | | | | | | | (-0.64) | (-2.06) | (-2.00) |
| % of Vil. area in FUG | | | 884.3 | | | 805.1 | | | 913.0 |
| | | | (1.21) | | | (1.16) | | | (1.26) |
| Med. time to road | | | -10.68 | | | -7.490 | | | -5.273 |
| | | | (-0.37) | | | (-0.26) | | | (-0.18) |
| # killings 20km ar. | | | 0.132 | | | 0.187 | | | 0.288 |
| | | | (0.09) | | | (0.12) | | | (0.20) |
| Vil. elevation: mean | | | 0.711 | | | 0.720 | | | 0.765 |
| | | | (1.43) | | | (1.47) | | | (1.52) |
| Vil. elevation: std. dev. | | | -2.745 | | | -2.187 | | | -2.840 |
| | | | (-1.52) | | | (-1.24) | | | (-1.55) |
| Vil. snow cover | | | -16829.9 | | | -45952.5 | | | -39349.6 |
| | | | (-0.22) | | | (-0.59) | | | (-0.51) |
| Rainfall z-score | | | -321.0 | | | -298.6 | | | -317.2 |
| | | | (-1.60) | | | (-1.52) | | | (-1.58) |
| Monsoon GDD | | | 0.399 | | | 0.491 | | | 0.267 |
| | | | (0.53) | | | (0.67) | | | (0.35) |
| Cooling Degree Days | | | 0.993 | | | 1.255 | | | 1.258 |
| | | | (0.76) | | | (0.96) | | | (0.98) |
| Year F.E. | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Belt-Zone F.E. | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Village F.E. | Yes | No | No | Yes | No | No | Yes | No | No |
| Observations | 3590 | 3590 | 3590 | 3590 | 3590 | 3590 | 3590 | 3590 | 3590 |

Standard errors clustered at the village level, $t$-statistics in parentheses, $^{*} p < 0.1$, $^{**} p < 0.05$, $^{***} p < 0.01$

In Table 2.4, we reproduce the same analysis on fuel expenditures which exclude collected firewood (sawdust, coal, charcoal, LPG, kerosene, etc.). The results closely reflect those obtained for firewood: fuel expenditures increase with income and collection times. Under the reduced form presented in the last three columns of table 2.4, fuel expenditures decrease with agricultural occupations and farm-based assets (in particular livestock) but increase in non-farm based assets. Fuel expenditures are therefore used by households as a substitute to firewood collections when collection costs are high or occupations and asset ownership less based on farming. (We do not report the results based on the household panel, as the reduced number of observations and the lower within-household variability of the variables of interest make most coefficients insignificant).

We conclude these first results by rejecting the Poverty-Environment hypothesis: collections, together with other fuel expenditures, increase in income. Collection time have a robust and significant but relatively small impact on collections. The nature of occupations clearly matters, since households owning more farm-based assets, such as livestock and land, spent more time on agricultural activities, collect more firewood and buy less alternative fuels.

## 2.4 Firewood collection and the local ecology

We first provide a simple model corresponding to our estimation strategy. Let the amount of firewood collected by household $i$ in village $j$ at time $t$ be denoted by $C_{ijt}$. Under the reduced form specification, this is a function of various household assets $X_{kijt}$, the time taken to collect one unit of firewood $T_{jt}$ and various village characteristics $V_{zjt}$. In the preceding section we have estimated the following specification:

$$C_{ijt} = \sum \beta_k X_{kijt} + \phi T_{jt} + \sum \gamma_z V_{zjt} + \varepsilon_{ijt} \tag{2.1}$$

The amount of firewood available in a village depends on forest conditions, as measured by forest biomass, $B_{jt}$. The more biomass is available in a village, the lower the time necessary to collect firewood. To avoid simultaneity biases, we assume that the collection time at time $t$ depends on the biomass available at time $t-1$. We therefore have:

$$T_{jt} = \xi B_{jt-1} + \sum \eta_z V_{zjt} + \varepsilon_{jt} \tag{2.2}$$

which can be directly estimated. As collection times depend on forest biomass, equation (1) can also be rewritten as:

$$C_{ijt} = \sum \beta_k X_{kijt} + \nu B_{jt-1} + \sum \gamma_z V_{zjt} + \varepsilon_{ijt} \tag{2.3}$$

At the village level, the total amount of fuelwood removed per unit area [20] in a village at time $t$, $C_{vt}$, is equal to the sum of all individual collections divided by the area of the village, $A_v$, or to the average amount collected multiplied by the household density of the village, $\frac{N_{vt}}{A_v}$, where $N_{vt}$ represents the number of households in village $v$ at time $t$. We therefore have: $C_{vt} = \frac{\bar{C_{jt}} \times N_{vt}}{A_v}$. The change in forest biomass in a village is therefore equal to the natural growth of biomass minus the amounts collected. We can therefore estimate the following equation:

$$\Delta B_{jt} = B_{jt+1} - B_{jt-1} = \alpha + \varphi C_{vt} + \sigma B_{jt-1} + \sum \rho_z V_{zjt} + \varepsilon_{jt} \tag{2.4}$$

in which $\phi$ is expected to be negative, and $\sigma$ measures the effect of the existing biomass on its growth.

We now turn to the estimation of the last three equations. For robustness purposes, we provide in the appendix a similar set of estimates using as alternative measures of biomass the average measure of LAI and FPAR in November and December as this corresponds to a season during which there are very few clouds and most agricultural crops have been collected (see table 2.16, 2.15 and 2.17 in the appendix). Table 2.5 reports the results of regression of collection time on forest biomass, where the three different measures of biomass will be used alternatively: LAI, FPAR and NDVI. Columns 1, 4 and 7 present the simple correlation between these two variables and columns 2, 5 and 8 correspond to the specification proposed in equation (2.2) above, where various village controls are added. In the remaining three columns, we allow for the possibility that total collections in a village have an impact on current collection times, and we use the reduced form in household assets (measure as densities at the village level) to capture this possible effect.

20. The various biomass index used are averages per pixel, and are therefore measures of biomass per unit area. Hence the need to define village collections in terms of density per unit area.

As expected, forest biomass has a robust and significant negative impact on median collection times in a village. The coefficients estimated are relatively small in magnitude, as a one standard deviation increase in LAI (+7.37) results in a fall in the median collection time of only 0.20 hours (using column 2 estimated coefficient). This may partly be due to measurement errors. In particular, biomass measures, which are constructed as averages over the whole administrative area of a village, only imperfectly capture villagers' access to forest products. On the one hand, the latter go to specific forest patches which are not well captured by a village average. On the other hand, these patches may be located in neighbouring administrative villages, so that the administrative boundaries do not match perfectly the areas in which collection of forest products take place. By contrast, collection times are directly measured relative to the actual place of collection.

Interestingly, forest user groups (measured by the proportion of village area managed by an FUG) tend to increase the time needed to collect firewood, by about 1.3 hours. This may be due to a restricted access to part of the forests but also to the improved collection and lopping practices imposed by the FUG. However, as Forest User Groups are created voluntarily by villages, it is difficult to estimate their causal impact on firewood collections. Their creation and the time at which they were created are likely to be affected by prior pressures of deforestation as well as various unobserved political and economic factors. At the household level, membership in a FUG is also voluntary. Hence the right to collect from a community forest is not exogenous, even when one controls for village characteristics. Given our data, we therefore refrain from drawing any inferences regarding the role of the FUGs in forest conservation or regeneration [21]. Most of the asset densities and the other village variables are insignificant, with the exception of the altitude variability within a village, which measures ruggedness and is associated with longer collection times [22].

21. For various attempts at identifying the impact of community forest management in Asia, we again refer to Edmonds (2002), Somanathan et al. (2009) and Baland et al. (2010a).

22. In all regression at the village level, asset densities are not very significant, and will therefore be neglected. Their inclusion does not affect the results reported below.

Table 2.5 – Village median collection time

| | Median village collection time in hours per bhari | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| LAI $90^{th} percentile_{t-1}$ | -0.0400*** | -0.0270** | -0.0288** | | | | | | |
| | (-3.29) | (-2.01) | (-2.11) | | | | | | |
| FPAR $90^{th} percentile_{t-1}$ | | | | -0.0344*** | -0.0339*** | -0.0332*** | | | |
| | | | | (-4.27) | (-2.71) | (-2.61) | | | |
| NDVI winter max $_{t-1}$ | | | | | | | -0.000271** | -0.000293** | -0.000328** |
| | | | | | | | (-2.53) | (-2.08) | (-2.16) |
| % of Vil. area in FUG | | 1.392*** | 1.230** | | 1.373*** | 1.236** | | 1.490*** | 1.313** |
| | | (2.64) | (2.32) | | (2.60) | (2.32) | | (2.82) | (2.49) |
| Med. time to road | | -0.00214 | -0.0000797 | | -0.00348 | -0.00144 | | -0.00331 | -0.00195 |
| | | (-0.19) | (-0.01) | | (-0.32) | (-0.13) | | (-0.29) | (-0.17) |
| # killings 20km ar. | | 0.00181 | 0.00134 | | 0.00197* | 0.00153 | | 0.00183* | 0.00143 |
| | | (1.61) | (1.17) | | (1.78) | (1.36) | | (1.68) | (1.26) |
| Vil. elevation: mean | | 0.000130 | 0.000146 | | 0.0000382 | 0.0000683 | | 0.000138 | 0.000168 |
| | | (0.43) | (0.50) | | (0.13) | (0.24) | | (0.46) | (0.56) |
| Vil. elevation: std. dev. | | 0.00227*** | 0.00230*** | | 0.00240*** | 0.00241*** | | 0.00257*** | 0.00255*** |
| | | (3.79) | (3.65) | | (4.00) | (3.87) | | (4.29) | (4.08) |
| Vil. snow cover | | -11.48 | -12.57 | | -21.78 | -22.07 | | -21.81 | -24.92 |
| | | (-0.29) | (-0.32) | | (-0.55) | (-0.55) | | (-0.55) | (-0.63) |
| Rainfall z-score | | -0.169 | -0.171 | | -0.158 | -0.165 | | -0.181 | -0.187 |
| | | (-1.49) | (-1.50) | | (-1.39) | (-1.44) | | (-1.56) | (-1.62) |
| Monsoon GDD | | 0.000203 | 0.000160 | | 0.000102 | 0.0000643 | | -0.00000227 | -0.0000391 |
| | | (0.46) | (0.37) | | (0.23) | (0.15) | | (-0.00) | (-0.09) |
| Cooling Degree Days | | -0.0000854 | -0.000112 | | -0.000220 | -0.000240 | | -0.000284 | -0.000316 |
| | | (-0.13) | (-0.17) | | (-0.34) | (-0.37) | | (-0.44) | (-0.48) |
| Livestock density | | | -0.00126 | | | -0.00110 | | | -0.00107 |
| | | | (-0.66) | | | (-0.58) | | | (-0.55) |
| Farm land density | | | -0.00365 | | | -0.00313 | | | -0.00421 |
| | | | (-0.78) | | | (-0.66) | | | (-0.88) |
| Population density | | | 0.00151* | | | 0.00156* | | | 0.00160** |
| | | | (1.80) | | | (1.87) | | | (1.98) |
| Prop. child. density | | | -0.000513 | | | -0.00178 | | | -0.00479 |
| | | | (-0.06) | | | (-0.19) | | | (-0.51) |
| Education density | | | -0.00136** | | | -0.00129* | | | -0.00129* |
| | | | (-1.99) | | | (-1.88) | | | (-1.92) |
| Non-farm business density | | | 0.00185 | | | 0.00105 | | | 0.00265 |
| | | | (0.35) | | | (0.20) | | | (0.50) |
| Out-migrant density | | | 0.00788*** | | | 0.00746** | | | 0.00726** |
| | | | (2.61) | | | (2.47) | | | (2.45) |
| Year fixed-effect | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Belt-Zone fixed-effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 301 | 301 | 301 | 301 | 301 | 301 | 301 | 301 | 301 |

Standard errors robust to heteroskedasticity – $t$-statistics in parentheses, $^{*}p < 0.1,^{**} p < 0.05,^{***} p < 0.01$

Table 2.6 – Firewood collection

| | Firewood collections in number of bharis per year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| LAI $90^{th} percentile_{t-1}$ | 0.521*** | 0.663*** | 0.563*** | | | | | | |
| | (3.67) | (3.91) | (3.36) | | | | | | |
| FPAR $90^{th} percentile_{t-1}$ | | | | 0.235* | 0.548*** | 0.426* | | | |
| | | | | (2.36) | (3.30) | (2.58) | | | |
| NDVI winter max $_{t-1}$ | | | | | | | 0.00529*** | 0.00910*** | 0.00803*** |
| | | | | | | | (4.45) | (4.36) | (3.82) |
| Med. collection time | | | -3.573*** | | | -3.620*** | | | -3.576*** |
| | | | (-4.44) | | | (-4.48) | | | (-4.42) |
| Big livestock | 2.951*** | 2.723*** | 2.692*** | 2.954*** | 2.691*** | 2.667*** | 2.870*** | 2.694*** | 2.666*** |
| | (6.94) | (6.27) | (6.21) | (6.94) | (6.20) | (6.16) | (6.71) | (6.21) | (6.15) |
| Land owned, ha | 4.614** | 4.174** | 3.946* | 4.660** | 4.126** | 3.923* | 4.639** | 3.992* | 3.777* |
| | (2.94) | (2.62) | (2.47) | (2.95) | (2.58) | (2.44) | (2.94) | (2.51) | (2.36) |
| Household size | 6.337*** | 6.517*** | 6.545*** | 6.341*** | 6.520*** | 6.547*** | 6.345*** | 6.501*** | 6.531*** |
| | (11.96) | (12.31) | (12.41) | (11.93) | (12.29) | (12.40) | (11.98) | (12.30) | (12.41) |
| Prop. children | -2.572 | -3.741 | -3.862 | -2.316 | -3.606 | -3.723 | -2.451 | -3.384 | -3.563 |
| | (-0.62) | (-0.90) | (-0.94) | (-0.56) | (-0.87) | (-0.90) | (-0.59) | (-0.82) | (-0.86) |
| Avg. education | -2.214*** | -1.979*** | -2.056*** | -2.261*** | -2.001*** | -2.082*** | -2.218*** | -1.927*** | -2.007*** |
| | (-6.95) | (-6.10) | (-6.37) | (-7.06) | (-6.16) | (-6.44) | (-6.95) | (-5.93) | (-6.20) |
| = 1 if NFBus | -6.344** | -6.352** | -6.176** | -6.190** | -6.125** | -5.989** | -5.968** | -6.150** | -6.001** |
| | (-3.01) | (-2.98) | (-2.91) | (-2.92) | (-2.87) | (-2.81) | (-2.82) | (-2.89) | (-2.82) |
| # Migrants | -1.360 | -1.162 | -1.035 | -1.320 | -1.054 | -0.951 | -1.362 | -0.969 | -0.864 |
| | (-1.40) | (-1.20) | (-1.07) | (-1.36) | (-1.09) | (-0.99) | (-1.40) | (-1.00) | (-0.89) |
| % of Vil. area in FUG | | -13.82* | -8.824 | | -13.94* | -8.926 | | -16.68** | -11.31 |
| | | (-2.30) | (-1.42) | | (-2.31) | (-1.43) | | (-2.73) | (-1.79) |
| Med. time to road | | -0.237 | -0.244 | | -0.216 | -0.228 | | -0.185 | -0.198 |
| | | (-1.85) | (-1.88) | | (-1.68) | (-1.76) | | (-1.44) | (-1.52) |
| # killings 20km ar. | | 0.00613 | 0.0128 | | 0.00288 | 0.0102 | | 0.00627 | 0.0130 |
| | | (0.43) | (0.89) | | (0.20) | (0.71) | | (0.44) | (0.90) |
| Vil. elevation: mean | | 0.000146 | 0.000653 | | 0.000116 | 0.000332 | | 0.000970 | 0.00152 |
| | | (0.04) | (0.17) | | (0.03) | (0.08) | | (0.25) | (0.39) |
| Vil. elevation: std. dev. | | 0.0148 | 0.0228* | | 0.0136 | 0.0222* | | 0.00509 | 0.0143 |
| | | (1.72) | (2.56) | | (1.57) | (2.46) | | (0.56) | (1.50) |
| Vil. snow cover | | 42.44 | -20.38 | | 189.7 | 93.46 | | 311.9 | 217.4 |
| | | (0.07) | (-0.03) | | (0.31) | (0.15) | | (0.51) | (0.36) |
| Rainfall z-score | | -0.722 | -1.284 | | -0.721 | -1.249 | | -0.538 | -1.141 |
| | | (-0.42) | (-0.75) | | (-0.42) | (-0.72) | | (-0.31) | (-0.66) |
| Monsoon GDD | | -0.0138* | -0.0129* | | -0.0136* | -0.0131* | | -0.00629 | -0.00618 |
| | | (-2.14) | (-2.00) | | (-2.11) | (-2.02) | | (-0.94) | (-0.92) |
| Cooling Degree Days | | -0.00640 | -0.00638 | | -0.00467 | -0.00518 | | 0.00119 | 0.000390 |
| | | (-0.63) | (-0.63) | | (-0.46) | (-0.51) | | (0.12) | (0.04) |
| Year fixed-effect | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Belt-Zone fixed-effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 3590 | 3590 | 3590 | 3590 | 3590 | 3590 | 3590 | 3590 | 3590 |

Standard errors clustered at the village level – $t$-statistics in parentheses, $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

In table 2.6, we report the impact of forest biomass on household collections. Columns 2, 5, and 8 correspond to the specification given in equation (2.3) above. In columns 1, 4 and 7, we replace village controls by a village fixed effect, while in columns 3, 6 and 9, we additionally control for collection time. Forest biomass has a robust, positive but small impact on household collections. Thus, a one SD increase in LAI results in an increase in collections by about 3.8 bharis ($7.37 \times 00.521$). The alternative specifications and the other biomass measures provide somewhat larger estimates. For instance, a one SD increase in NDVI results in an increase in collections by 4.7 bharis ($887 \times 0.0053$). Introducing collection times as an additional control slightly reduces the estimated coefficient which remains significant. This implies that forest biomass has an impact on collections which is independent of its indirect impact through collection times. Forest biomass may be related to the easiness in collections, or to the collection of associated forest products that influence positively the collection of firewood, and these effects are not fully captured by collection times.

The effects of household assets are very consistent and similar to those obtained in the reduced form estimations presented in Table 2.3. Interestingly, Forest User Groups are correlated with reduced collections (of about 13 bharis) even if the coefficient is imprecisely estimated. When controlling for collection times, the coefficient is systematically lower and looses significance, which supports the idea that FUGs increase collection times. It remains negative which may be related to the improved collection or changing cooking and heating practices that may accompany the creation of a FUG. FUGs may also play a role in promoting alternative energy sources.

In Table 2.7, we report the estimations obtained with fuel expenditures as the dependent variable, following the same specifications as in Table 2.6. The results there closely follow the previous results. Fuel expenditures decrease in villages with more abundant forest biomass or lower collection times. Agricultural assets decrease those expenditures, while education and non-farm business assets increase them by a substantial amount. The importance of FUGs in the village also increase fuel expenditures, which therefore again appear as a substitute to firewood collection.

Table 2.7 – Fuel expendituтes

| | Fuel expenditures in $NPR_{2010}$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| LAI $90^{th} percentile_{t-1}$ | -60.63*** | -42.94*** | -33.73** | | | | | | |
| | (-5.75) | (-3.76) | (-2.90) | | | | | | |
| FPAR $90^{th} percentile_{t-1}$ | | | | -43.07*** | -41.12*** | -30.00** | | | |
| | | | | (-5.19) | (-3.83) | (-2.72) | | | |
| NDVI winter max $_{t-1}$ | | | | | | | -0.575*** | -0.707*** | -0.610** |
| | | | | | | | (-4.77) | (-3.86) | (-3.29) |
| Med. collection time | | | 331.2*** | | | 330.6*** | | | 325.5*** |
| | | | (5.31) | | | (5.31) | | | (5.34) |
| Big livestock | -161.2*** | -138.0*** | -135.1*** | -159.1*** | -135.4*** | -133.3*** | -152.8*** | -135.6*** | -133.0*** |
| | (-5.10) | (-4.38) | (-4.34) | (-5.00) | (-4.28) | (-4.27) | (-4.80) | (-4.28) | (-4.26) |
| Land owned, ha | -93.17 | -123.8 | -102.7 | -98.38 | -117.6 | -99.07 | -96.23 | -106.4 | -86.78 |
| | (-0.98) | (-1.28) | (-1.06) | (-1.03) | (-1.21) | (-1.02) | (-1.02) | (-1.10) | (-0.89) |
| Household size | 137.6*** | 136.0*** | 133.3*** | 139.2*** | 135.7*** | 133.2*** | 136.4*** | 137.2*** | 134.4*** |
| | (3.46) | (3.39) | (3.35) | (3.49) | (3.38) | (3.34) | (3.44) | (3.42) | (3.38) |
| Prop. children | -480.4 | -483.7 | -472.5 | -500.5 | -488.7 | -478.1 | -496.6 | -505.0 | -488.7 |
| | (-1.57) | (-1.58) | (-1.56) | (-1.63) | (-1.60) | (-1.57) | (-1.62) | (-1.65) | (-1.61) |
| Avg. education | 211.3*** | 209.5*** | 216.7*** | 218.6*** | 210.1*** | 217.5*** | 211.9*** | 204.2*** | 211.5*** |
| | (7.59) | (7.79) | (8.06) | (7.77) | (7.76) | (8.04) | (7.62) | (7.73) | (8.02) |
| = 1 if NFBus | 475.6** | 438.4** | 422.1** | 439.3** | 422.5** | 410.1** | 435.7** | 424.2** | 410.6** |
| | (3.21) | (2.96) | (2.86) | (2.94) | (2.84) | (2.77) | (2.90) | (2.86) | (2.77) |
| # Migrants | -141.7* | -143.2* | -155.0* | -139.5* | -151.6* | -161.0* | -142.7* | -158.5* | -168.1** |
| | (-2.16) | (-2.22) | (-2.41) | (-2.13) | (-2.35) | (-2.51) | (-2.19) | (-2.47) | (-2.63) |
| % of Vil. area in FUG | | 1352.7** | 889.4* | | 1350.4** | 892.5* | | 1561.1** | 1072.1* |
| | | (2.87) | (2.00) | | (2.87) | (2.01) | | (3.27) | (2.38) |
| Med. time to road | | -6.671 | -6.058 | | -8.400 | -7.266 | | -10.87 | -9.763 |
| | | (-0.63) | (-0.58) | | (-0.80) | (-0.70) | | (-1.01) | (-0.92) |
| # killings 20km ar. | | 0.843 | 0.225 | | 1.065 | 0.396 | | 0.804 | 0.192 |
| | | (1.11) | (0.31) | | (1.41) | (0.54) | | (1.05) | (0.26) |
| Vil. elevation: mean | | 0.598* | 0.551* | | 0.555* | 0.536 | | 0.477 | 0.427 |
| | | (2.17) | (2.01) | | (1.99) | (1.92) | | (1.85) | (1.66) |
| Vil. elevation: std. dev. | | -1.961* | -2.710*** | | -1.856* | -2.638*** | | -1.188 | -2.021* |
| | | (-2.52) | (-3.44) | | (-2.37) | (-3.33) | | (-1.49) | (-2.51) |
| Vil. snow cover | | -45458.9 | -39636.4 | | -56484.0 | -47696.8 | | -66383.1 | -57782.9 |
| | | (-0.98) | (-0.87) | | (-1.21) | (-1.03) | | (-1.40) | (-1.23) |
| Rainfall z-score | | -343.6*** | -291.6** | | -337.8** | -289.5** | | -350.4*** | -295.5** |
| | | (-3.35) | (-2.77) | | (-3.28) | (-2.75) | | (-3.45) | (-2.83) |
| Monsoon GDD | | 0.131 | 0.0531 | | 0.0756 | 0.0292 | | -0.507 | -0.516 |
| | | (0.30) | (0.13) | | (0.18) | (0.07) | | (-1.20) | (-1.23) |
| Cooling Degree Days | | 1.158 | 1.156 | | 1.008 | 1.054 | | 0.542 | 0.614 |
| | | (1.60) | (1.62) | | (1.41) | (1.49) | | (0.76) | (0.86) |
| Year fixed-effect | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Belt-Zone fixed-effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 3590 | 3590 | 3590 | 3590 | 3590 | 3590 | 3590 | 3590 | 3590 |

Standard errors clustered at the village level – $t$-statistics in parentheses, $^{*} p < 0.1$, $^{**} p < 0.05$, $^{***} p < 0.01$

Table 2.8 – Degradation of forest and firewood collections

| | $\Delta$ LAI $90^{th}$ percentile | | | $\Delta$ FPAR $90^{th}$ percentile | | | $\Delta$ NDVI winter max | | |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Collection densities | -0.0000780 | -0.000148$^{*}$ | -0.000209$^{**}$ | -0.0000786 | -0.000143$^{*}$ | -0.000208$^{**}$ | -0.00650 | -0.00996 | -0.00966 |
| | (-1.27) | (-1.89) | (-2.46) | (-1.08) | (-1.71) | (-2.37) | (-1.31) | (-1.62) | (-1.61) |
| LAI $90^{th} percentile_{t-1}$ | -0.121$^{***}$ | -0.167$^{***}$ | | | | | | | |
| | (-4.28) | (-5.14) | | | | | | | |
| LAI $90^{th} percentile_{t-2}$ | | | -0.155$^{***}$ | | | | | | |
| | | | (-4.84) | | | | | | |
| FPAR $90^{th} percentile_{t-1}$ | | | | -0.0516$^{**}$ | -0.153$^{***}$ | | | | |
| | | | | (-2.49) | (-4.41) | | | | |
| FPAR $90^{th} percentile_{t-2}$ | | | | | | -0.141$^{***}$ | | | |
| | | | | | | (-4.26) | | | |
| NDVI winter max $_{t-1}$ | | | | | | | -0.0207 | -0.0474 | |
| | | | | | | | (-1.17) | (-1.57) | |
| NDVI winter max $_{t-2}$ | | | | | | | | | -0.0803$^{***}$ |
| | | | | | | | | | (-3.24) |
| % of Vil. area in FUG | | 0.997 | -0.872 | | 0.159 | -1.658 | | -48.65 | -94.97 |
| | | (0.98) | (-0.66) | | (0.13) | (-1.26) | | (-0.61) | (-1.42) |
| Med. time to road | | 0.00691 | -0.0276 | | 0.0566$^{*}$ | -0.0183 | | -1.168 | -4.951$^{***}$ |
| | | (0.35) | (-1.11) | | (1.81) | (-0.59) | | (-0.71) | (-3.64) |
| # killings 20km ar. | | 0.00179 | 0.000585 | | 0.00111 | 0.00215 | | -0.0389 | -0.152 |
| | | (0.70) | (0.24) | | (0.40) | (0.87) | | (-0.25) | (-0.97) |
| Vil. elevation: mean | | -0.00196$^{***}$ | -0.00204$^{***}$ | | -0.00279$^{***}$ | -0.00357$^{***}$ | | -0.00334 | -0.0379 |
| | | (-3.41) | (-2.99) | | (-3.32) | (-4.47) | | (-0.06) | (-0.88) |
| Vil. elevation: std. dev. | | 0.000650 | -0.000904 | | 0.00118 | -0.000152 | | 0.0739 | 0.214$^{*}$ |
| | | (0.45) | (-0.60) | | (0.66) | (-0.08) | | (0.58) | (1.95) |
| Vil. snow cover | | 96.40 | 24.31 | | -22.06 | 53.37 | | 264.7 | 5738.8 |
| | | (0.92) | (0.21) | | (-0.16) | (0.35) | | (0.03) | (0.96) |
| Rainfall z-score | | -0.291 | -0.907$^{***}$ | | -0.213 | -0.514 | | -57.43$^{***}$ | -49.59$^{**}$ |
| | | (-1.10) | (-3.16) | | (-0.64) | (-1.55) | | (-2.73) | (-2.44) |
| Monsoon GDD | | -0.00117 | -0.00180 | | -0.00156 | -0.00183 | | -0.0480 | -0.0782 |
| | | (-1.15) | (-1.49) | | (-1.11) | (-1.28) | | (-0.54) | (-1.09) |
| Cooling Degree Days | | -0.00116 | 0.000611 | | -0.000515 | -0.000135 | | -0.106 | -0.300$^{***}$ |
| | | (-0.66) | (0.34) | | (-0.23) | (-0.06) | | (-0.84) | (-3.12) |
| Year fixed-effect | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Belt-Zone fixed-effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 301 | 301 | 301 | 301 | 301 | 301 | 301 | 301 | 301 |

Standard errors robust to heteroskedasticity – $t$-statistics in parentheses, $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

We now turn to examining the possible impact of firewood collections on forest biomass, and report the estimations based on equation (2.4). For each of the three forest biomass measures, we first report the simple correlation between changes in biomass between year $t-1$ and $t+1$ and village collections in year $t$, controlling for the initial stock of biomass [23]. As argued above, village collections are measured as densities, i.e. total collection per unit area, since biomass is also measured as an average per unit area. In the second column (col. 2, 5 and 8), we control for all the relevant village variables and therefore follow exactly the specification given in equation (4). A robustness check is reported in the third column (cols. 3, 6 and 9), in which the change in biomass is measured as the change between the year $t-2$ and year $t+1$, controlling for the stock in $t-2$.

Overall, village collections reduce biomass, even though the coefficient is not always precisely estimated. As discussed before, this is partly due to the measurement errors related to the use of biomass averages over the administrative boundaries of the village, which do not correspond to the actual collection points in the forest. However, the results are consistent across the three measures of biomass. Using the estimated coefficient in column (2), total collections in a village correspond to a 1.9% reduction in LAI (0.000148*3276.17/25.4). The estimated impact on FPAR are smaller in relative terms, as total collections correspond to a fall of about 0.7% in FPAR. These can be compared to a rough calculation based on the stock of wood in Nepalese forests (Oli and Shrestha, 2009). The average above ground stock in forest is estimated to be around 200 tons per hectare, while village collections represent a removal of about 2.5 ton per hectare (30 kgs per bharis * 3276 bharis per square kilometers * 0.40 forest per unit area), which corresponds to a 1.25% decrease in the stock of wood. The larger estimates obtained with the LAI measure comes from the fact that LAI is based on the density of leaves, and a lot of firewood is collected through cutting branches (lopping) instead of trees (Baland et al., 2010a) or collecting dead wood which does not affect these measures but is accounted in measures of wood biomass. Collections should therefore have a larger impact on LAI than on the other two measures.

23. More precisely, we took the average in the biomass stock over the first 12 of the 24 months that precede the date of the survey in the village, since collections were reported 'over the last 12 months'

## 2.5 Implied growth effects

In this short section, we discuss and summarize our main findings. Our enquiry started with the observation that, across the two cross-sections of the Nepal LSMS, average collections per household fell from 85.8 to 78.9 bharis, a fall of 7.1 bharis. Given the increase in the number of households in the villages, this implied that total collections in a village remained unchanged between 2003 and 2011. If we rely on the Engel curve, with the large increase in consumption observed during the period (from 75 to 119 thousands NPR), household collections should have increased by 8.17 bharis (using Table 1, equation 3). The increase in the average village median collection time, from 3.42 to 3.83 is at best responsible for a fall of about 1.62 bharis. These predicted changes are thus very far from the observed ones, and we therefore conclude that the Engel curve is a very poor predictor of future changes.

The use of reduced forms allowed us to investigate in more details the role played by occupational patterns, as measured by the productive assets owned by the household. Using the Engel curves but controlling for occupations (Table 2.3, equation 3), we find that occupational patterns matter but the predicted changes (of -3.05 bharis) are again too small to account for the fall in collections. By contrast, the reduced form based on productive assets provides a much better prediction (Table 2.3, equation 6)[24]. Livestock holdings fell by 0.38 over the period, land area by 0.07, household size by 0.23, while education increased by 0.75 and the proportion of households owning non-farm assets increased by 0.06. These changes led to a fall of respectively 1.1, 0.3, 1.5, 1.7 and 0.4 bharis per household. Taken together, the observed changes in asset holding predict a fall in the number of bharis collected of 5 bharis. Changes in collection time accounts for a fall of 1.3 bharis. We can therefore conclude that most of the observed changes can be explained by rising collection times and the nature of growth, as measured by the changing structure of household productive assets.

Another important question is whether collections would fall fast enough when excessive, through their impact on forest biomass and collection times. For the sake of the argument, consider that collections caused a 20% reduction in biomass, i.e. a fall of 5 units in LAI. According to Table 2.5 (col. 3), such a fall increases

24. We discuss here only coefficients that were precisely estimated.

collection times by 0.14 hours. Using the estimates in table 2.6 (col. 3), these changes should reduce firewood collection by 3.3 bharis or 4%, (0.6% through the increase in collection time, and 3.4% through the direct impact of biomass on collections). These return effects of a degraded biomass on collections are therefore very small, pointing again to the low sensitivity of collections to a degrading forest biomass, either directly or indirectly through increasing collection times. This return effect is much lower than the direct impact of collections on biomass. This being said, we must again stress the fact that over the period analysed, the overall forest biomass remained essentially stable, so that this question remains essentially hypothetical in this context.

## 2.6 Relation to existing literature and concluding comments

The only longitudinal study on deforestation in South Asia that we are aware of is Foster and Rosenzweig (2003). They used a panel of 250 Indian villages over the last three decades of the 20th century. The satellite imagery data showed evidence of reforestation, while the household data showed increased demand for wood and wood products accompanying the rise in their living standards. They argue that the increasing demand for wood products induced reforestation. Our results are broadly consistent with theirs, despite pertaining to a different country and period of analysis. In particular, the hilly and mountainous regions of Nepal do differ from India in a number of important characteristics: (1) the forests are abundant relative to the population, (2) the forests are still of an open access nature (though possibly regulated by the FUG), which involves that households collect according to their needs, and, most importantly, (3) the demand for heating energy in the winter constitutes an important and relatively inelastic component of the demand for firewood, for which few substitutes are available [25].

Numerous cross-section studies on Nepal and rural India suggest that firewood is a normal good for all but the wealthiest households (see in particular Heltberg et al. (2000); Arnold et al. (2006); Adhikari et al. (2004); Baland et al. (2006); Gundimeda and Kohlin (2008)). The switch of high incomes households to higher quality but more expensive substitutes (gas or kerosene) is known as the 'energy-

25. In the same vein, Nepal et al. show that improved cookstoves do not affect firewood collections in Nepal. This finding supports the idea of an inelastic demand for firewood.

ladder' hypothesis, and is often viewed as an important mechanism behind the EKC (see Arnold et al, 2003). Recent evidence from China suggests that firewood is becoming an inferior good in China, with coal being used as a superior alternative (Démurger and Fournier, 2011). Chaudhuri and Pfaff (2003) find evidence of an EKC in indoor air pollution, using a cross-sectional analysis of the Pakistan World Bank LSMS while controlling for village dummies. While richer households tend to consume more energy, they switch to cleaner and more efficient fuels (kerosene) which reduces the amount of indoor pollution. Baland et al. (2006) also find that the demand for firewood in Indian Himalayas to be sensitive to the price of kerosene. These earlier findings are consistent with our estimations of the Engel curves for fuelwood but also for expenditures on other fuels. However, the evidence concerning EKC in preceding literature has been based on cross-sectional analyses, without checks for robustness with respect to unobserved heterogeneity, functional form or measurement error. More importantly, the nature of growth has not been examined in this literature. Closest to our analysis, our previous paper Baland et al. (2010b), based on a cross section Nepal LSMS of 1995, argued that the structure of productive assets was a major determinant of firewood collections [26]. Our earlier findings there are strengthened by our main results above.

Our results on CFUGs tend to support the findings of Somanathan et al. (2009) and, to a lower extent, of Baland et al. (2010a), who showed that the impact of community forestry in India on the state of the forest was quite limited. While the presence of CFUG is associated with higher collection times and lower collections, they do not seem to affect forest biomass in our estimates. Our results are also consistent with those obtained by Edmonds (2002) who found that the creation of CFUGs in Nepal tends to reduce fuelwood extraction from forests (see also the recent surveys by Kanel (2008) and Shyamsundar and Ghate (2011)). The methodology used in those studies deals explicitly with the possibility of a selection bias in the creation of the FUGs, a problem that we could not satisfactorily address with the present data set.

26. See Bluffstone (1995) for similar cross-sectional evidence concerning the role of occupational structure in firewood collections.

# 2.7 Appendix

## 2.7.1 Additional tables

Table 2.9 – Descriptive statistics: household level variables

| Variable | Median | Mean | Std. Dev. | Minimum | Maximum | Observations |
|---|---|---|---|---|---|---|
| Wood | 70 | 81.75 | 59.2 | 0 | 500 | 3590 |
| Collection time | 3.5 | 3.75 | 1.83 | .02 | 12 | 3344 |
| Fuel expenditures | 844.63 | 2086.1 | 3920.95 | 0 | 57266.64 | 3590 |
| Consumption exp. (1000$NPR_{2010}$) | 87.52 | 101.01 | 63.65 | 6.98 | 860.77 | 3590 |
| Prop. agri. worktime | .91 | .76 | .3 | 0 | 1 | 3590 |
| Big livestock | 3 | 3.3 | 2.72 | 0 | 25 | 3590 |
| Land owned, ha | .46 | .64 | .71 | 0 | 10.38 | 3590 |
| Household size | 5 | 4.88 | 2.2 | 1 | 17 | 3590 |
| Prop. children | .4 | .38 | .24 | 0 | 1 | 3590 |
| Avg. education | 2.33 | 2.85 | 2.89 | 0 | 17 | 3590 |
| = 1 if NFBus | 0 | .26 | .44 | 0 | 1 | 3590 |
| # Migrants | 0 | .64 | .88 | 0 | 8 | 3590 |

Descriptive statistics for the repeated cross-sections of NLSS in rural villages. All monetary values expressed in NPR2010

Table 2.10 – Descriptive statistics: household level variables in 2003

| Variable | Median | Mean | Std. Dev. | Minimum | Maximum | Observations |
|---|---|---|---|---|---|---|
| Wood | 72 | 85.84 | 55.2 | 0 | 360 | 1474 |
| Collection time | 3 | 3.53 | 1.71 | .02 | 12 | 1383 |
| Fuel expenditures | 812.14 | 1379.62 | 2613.21 | 0 | 57266.64 | 1474 |
| Consumption exp. (1000$NPR_{2010}$) | 64.10 | 74.92 | 47.43 | 6.98 | 449.37 | 1474 |
| Prop. agri. worktime | .97 | .82 | .27 | 0 | 1 | 1474 |
| Big livestock | 3 | 3.53 | 2.92 | 0 | 25 | 1474 |
| Land owned, ha | .48 | .68 | .76 | 0 | 9.81 | 1474 |
| Household size | 5 | 5.02 | 2.24 | 1 | 17 | 1474 |
| Prop. children | .4 | .39 | .24 | 0 | 1 | 1474 |
| Avg. education | 1.67 | 2.41 | 2.7 | 0 | 13.67 | 1474 |
| = 1 if NFBus | 0 | .22 | .42 | 0 | 1 | 1474 |
| # Migrants | 0 | .4 | .67 | 0 | 6 | 1474 |

Descriptive statistics for the repeated cross-sections of NLSS in rural villages. All monetary values expressed in NPR2010.

Table 2.11 – Descriptive statistics: household level variables in 2010

| Variable | Median | Mean | Std. Dev. | Minimum | Maximum | Observations |
|---|---|---|---|---|---|---|
| Wood | 60 | 78.91 | 61.68 | 0 | 500 | 2116 |
| Collection time | 4 | 3.91 | 1.9 | .5 | 10 | 1961 |
| Fuel expenditures | 884.47 | 2578.22 | 4554.36 | 0 | 52486.48 | 2116 |
| Consumption exp. ($1000NPR_{2010}$) | 106.29 | 119.19 | 67.11 | 9.05 | 860.77 | 2116 |
| Prop. agri. worktime | .86 | .72 | .32 | 0 | 1 | 2116 |
| Big livestock | 3 | 3.15 | 2.56 | 0 | 20 | 2116 |
| Land owned, ha | .43 | .61 | .66 | 0 | 10.38 | 2116 |
| Household size | 5 | 4.79 | 2.16 | 1 | 16 | 2116 |
| Prop. children | .4 | .37 | .24 | 0 | 1 | 2116 |
| Avg. education | 2.67 | 3.16 | 2.98 | 0 | 17 | 2116 |
| = 1 if NFBus | 0 | .28 | .45 | 0 | 1 | 2116 |
| # Migrants | 1 | .8 | .97 | 0 | 8 | 2116 |

Descriptive statistics for the repeated cross-sections of NLSS in rural villages. All monetary values expressed in NPR2010.

Table 2.12 – Descriptive statistics: village level variables

| Variable | Median | Mean | Std. Dev. | Minimum | Maximum | Observations |
|---|---|---|---|---|---|---|
| Collection densities | 2740.1 | 3276.17 | 2471.27 | 42.41 | 22515.49 | 301 |
| $\Delta LAI$ p$90_{t-1}^{t+1}$ | -1.28 | -1.41 | 2.93 | -14.5 | 6.8 | 301 |
| $\Delta FPAR$ p$90_{t-1}^{t+1}$ | -1.67 | -1.59 | 3.67 | -13.13 | 9.89 | 301 |
| $\Delta LAI$ p$90_{t-2}^{t+1}$ | -.81 | -.89 | 3.22 | -11.57 | 10.68 | 301 |
| $\Delta FPAR$ p$90_{t-2}^{t+1}$ | -.52 | -.55 | 3.64 | -11.07 | 11.33 | 301 |
| $\Delta LAI$ winter mean$_{t-1}^{t+1}$ | -.42 | -.37 | 1.21 | -3.98 | 5.16 | 301 |
| $\Delta FPAR$ winter mean$_{t-1}^{t+1}$ | -.16 | -.34 | 2.6 | -7.76 | 9.45 | 301 |
| $\Delta LAI$ winter mean$_{t-2}^{t+1}$ | -.72 | -.63 | 1.79 | -5.59 | 5.85 | 301 |
| $\Delta FPAR$ winter mean$_{t-2}^{t+1}$ | -.59 | -.12 | 4.14 | -8.95 | 13.29 | 301 |
| $\Delta NDVI_{t-1}^{t+1}$ | 55.21 | 59.35 | 210.76 | -615.46 | 765.33 | 301 |
| $\Delta NDVI_{t-2}^{t+1}$ | 137.88 | 161.1 | 198.91 | -488.65 | 769.82 | 301 |
| LAI $90^{th} percentile_{t-1}$ | 25.69 | 25.4 | 7.37 | 1.72 | 50.43 | 301 |
| LAI $90^{th} percentile_{t-2}$ | 24.86 | 24.87 | 7.26 | 1.69 | 45 | 301 |
| LAI winter average$_{t-1}$ | 14.25 | 14.34 | 4.03 | .99 | 29.18 | 301 |
| LAI winter average$_{t-2}$ | 14.54 | 14.6 | 4.25 | 1.06 | 31.63 | 301 |
| FPAR $90^{th} percentile_{t-1}$ | 67.78 | 66.25 | 10.07 | 8.73 | 85.29 | 301 |
| FPAR $90^{th} percentile_{t-2}$ | 66.86 | 65.21 | 9.93 | 8.5 | 83.86 | 301 |
| FPAR winter average$_{t-1}$ | 46.11 | 45.36 | 7.60 | 5.5 | 63.18 | 301 |
| FPAR winter average$_{t-2}$ | 45.93 | 45.13 | 8.21 | 5.62 | 66.77 | 301 |
| NDVI winter max $_{t-1}$ | 7041.65 | 6898.53 | 887.98 | 1327.15 | 8491.89 | 301 |
| NDVI winter max $_{t-2}$ | 6891.5 | 6796.78 | 887.67 | 1448.34 | 8377.78 | 301 |
| Med. collection time | 3.38 | 3.66 | 1.38 | 1 | 8 | 301 |
| % of Vil. area in FUG | .13 | .18 | .18 | 0 | 1 | 301 |
| Med. time to road | 3.13 | 7.69 | 11.2 | 0 | 80 | 301 |
| # killings 20km ar. | 101 | 121.65 | 92.89 | 0 | 698 | 301 |
| Vil. snow cover * 1000 | .37 | 2.92 | 8.51 | 0 | 62.11 | 301 |
| Rainfall z-score | -.45 | -.31 | .99 | -2.32 | 1.53 | 301 |
| Monsoon GDD | 1327.45 | 1210.26 | 396.37 | 0 | 1815.29 | 301 |
| Cooling Degree Days | 9.29 | 161.08 | 493.23 | 0 | 4042.55 | 301 |
| VDC area in $km^2$ | 25.6 | 45.23 | 88.95 | 2.36 | 815.01 | 301 |
| Village # HH. | 917 | 1076.16 | 705.14 | 125 | 4692 | 301 |

Descriptive statistics for the repeated cross-sections of NLSS in rural villages.

Table 2.13 – Descriptive statistics: village level variables in 2003

| Variable | Median | Mean | Std. Dev. | Minimum | Maximum | Observations |
|---|---|---|---|---|---|---|
| Collection densities | 2700.06 | 3315.75 | 2436.23 | 42.41 | 15716.64 | 123 |
| $\Delta LAI$ p$90_{t-1}^{t+1}$ | -.64 | -.76 | 2.96 | -14.5 | 6.8 | 123 |
| $\Delta FPAR$ p$90_{t-1}^{t+1}$ | -.13 | -.22 | 3.83 | -12.78 | 9.89 | 123 |
| $\Delta LAI$ p$90_{t-2}^{t+1}$ | -.5 | -.26 | 3.4 | -9.6 | 10.68 | 123 |
| $\Delta FPAR$ p$90_{t-2}^{t+1}$ | .9 | .8 | 3.93 | -11.07 | 11.33 | 123 |
| $\Delta LAI$ winter mean$_{t-1}^{t+1}$ | -.05 | .03 | 1.25 | -3.37 | 5.16 | 123 |
| $\Delta FPAR$ winter mean$_{t-1}^{t+1}$ | .83 | .76 | 2.46 | -6.18 | 9.45 | 123 |
| $\Delta LAI$ winter mean$_{t-2}^{t+1}$ | -.07 | .25 | 1.81 | -3.84 | 5.85 | 123 |
| $\Delta FPAR$ winter mean$_{t-2}^{t+1}$ | 1.94 | 2.63 | 4.16 | -6.72 | 13.29 | 123 |
| $\Delta NDVI_{t-1}^{t+1}$ | 41.92 | 52.97 | 181.53 | -432.45 | 464.5 | 123 |
| $\Delta NDVI_{t-2}^{t+1}$ | 152.83 | 170.25 | 191.57 | -231.18 | 662.25 | 123 |
| LAI $90^{th} percentile_{t-1}$ | 24.92 | 24.48 | 7.37 | 1.72 | 43.56 | 123 |
| LAI $90^{th} percentile_{t-2}$ | 24.33 | 23.98 | 7.35 | 1.69 | 45 | 123 |
| LAI winter average$_{t-1}$ | 14.22 | 14.33 | 4.2 | .99 | 23.71 | 123 |
| LAI winter average$_{t-2}$ | 14.1 | 14.1 | 4.23 | 1.06 | 22.59 | 123 |
| FPAR $90^{th} percentile_{t-1}$ | 66 | 64.36 | 10.68 | 8.73 | 83.78 | 123 |
| FPAR $90^{th} percentile_{t-2}$ | 64.79 | 63.34 | 10.34 | 8.5 | 81.33 | 123 |
| FPAR winter average$_{t-1}$ | 46.11 | 45.18 | 8.24 | 5.5 | 58.88 | 123 |
| FPAR winter average$_{t-2}$ | 44.14 | 43.32 | 8.62 | 5.62 | 56.82 | 123 |
| NDVI winter max $_{t-1}$ | 6945.72 | 6769.46 | 951.69 | 1327.15 | 8224.18 | 123 |
| NDVI winter max $_{t-2}$ | 6846.12 | 6652.19 | 963.39 | 1448.34 | 8377.78 | 123 |
| Med. collection time | 3 | 3.42 | 1.27 | 1 | 8 | 123 |
| % of Vil. area in FUG | .1 | .14 | .14 | 0 | .64 | 123 |
| Med. time to road | 5 | 10.65 | 14.47 | .08 | 80 | 123 |
| # killings 20km ar. | 56 | 78.67 | 64.97 | 0 | 354 | 123 |
| Vil. snow cover * 1000 | .48 | 3.36 | 9.96 | 0 | 62.11 | 123 |
| Rainfall z-score | .72 | .59 | .65 | -1.39 | 1.53 | 123 |
| Monsoon GDD | 1372.6 | 1249.61 | 373.98 | 27.85 | 1672.61 | 123 |
| Cooling Degree Days | 16.6 | 178.68 | 526.18 | 0 | 3836.66 | 123 |
| VDC area in $km^2$ | 24.79 | 46.57 | 96.84 | 2.36 | 776.85 | 123 |
| Village # HH. | 837 | 970.89 | 557.06 | 125 | 3349 | 123 |

Descriptive statistics for the repeated cross-sections of NLSS in rural villages.

Table 2.14 – Descriptive statistics: village level variables in 2010

| Variable | Median | Mean | Std. Dev. | Minimum | Maximum | Observations |
|---|---|---|---|---|---|---|
| Collection densities | 2745.6 | 3248.82 | 2501.67 | 55.91 | 22515.49 | 178 |
| $\Delta LAI$ p90$_{t-1}^{t+1}$ | -1.56 | -1.87 | 2.84 | -13.14 | 4.18 | 178 |
| $\Delta FPAR$ p90$_{t-1}^{t+1}$ | -2.38 | -2.53 | 3.25 | -13.13 | 7.12 | 178 |
| $\Delta LAI$ p90$_{t-2}^{t+1}$ | -.9 | -1.32 | 3.02 | -11.57 | 5.75 | 178 |
| $\Delta FPAR$ p90$_{t-2}^{t+1}$ | -1.45 | -1.49 | 3.12 | -10.89 | 7.92 | 178 |
| $\Delta LAI$ winter mean$_{t-1}^{t+1}$ | -.58 | -.64 | 1.1 | -3.98 | 1.6 | 178 |
| $\Delta FPAR$ winter mean$_{t-1}^{t+1}$ | -1.03 | -1.1 | 2.42 | -7.76 | 4.12 | 178 |
| $\Delta LAI$ winter mean$_{t-2}^{t+1}$ | -1.23 | -1.24 | 1.52 | -5.59 | 3.11 | 178 |
| $\Delta FPAR$ winter mean$_{t-2}^{t+1}$ | -1.97 | -2.01 | 2.88 | -8.95 | 6.26 | 178 |
| $\Delta NDVI_{t-1}^{t+1}$ | 66.24 | 63.76 | 229.18 | -615.46 | 765.33 | 178 |
| $\Delta NDVI_{t-2}^{t+1}$ | 128.61 | 154.77 | 204.12 | -488.65 | 769.82 | 178 |
| LAI $90^{th} percentile_{t-1}$ | 26.34 | 26.04 | 7.33 | 4.71 | 50.43 | 178 |
| LAI $90^{th} percentile_{t-2}$ | 25.35 | 25.49 | 7.15 | 3.99 | 42.57 | 178 |
| LAI winter average$_{t-1}$ | 14.29 | 14.35 | 3.92 | 2.2 | 29.18 | 178 |
| LAI winter average$_{t-2}$ | 14.9 | 14.94 | 4.24 | 2.39 | 31.63 | 178 |
| FPAR $90^{th} percentile_{t-1}$ | 68.91 | 67.56 | 9.44 | 14.11 | 85.29 | 178 |
| FPAR $90^{th} percentile_{t-2}$ | 68.12 | 66.51 | 9.44 | 12.9 | 83.86 | 178 |
| FPAR winter average$_{t-1}$ | 46.11 | 45.48 | 7.14 | 8.48 | 63.18 | 178 |
| FPAR winter average$_{t-2}$ | 47.45 | 46.38 | 7.7 | 8.52 | 66.77 | 178 |
| NDVI winter max $_{t-1}$ | 7115.3 | 6987.72 | 832.22 | 1976.44 | 8491.89 | 178 |
| NDVI winter max $_{t-2}$ | 6986.38 | 6896.7 | 819.29 | 1857.98 | 8148.56 | 178 |
| Med. collection time | 3.5 | 3.83 | 1.43 | 1 | 8 | 178 |
| % of Vil. area in FUG | .15 | .2 | .19 | 0 | 1 | 178 |
| Med. time to road | 2.5 | 5.65 | 7.61 | 0 | 40 | 178 |
| # killings 20km ar. | 126.5 | 151.35 | 97.69 | 0 | 698 | 178 |
| Vil. snow cover * 1000 | .3 | 2.61 | 7.37 | 0 | 60.21 | 178 |
| Rainfall z-score | -.9 | -.930 | .65 | -2.32 | .96 | 178 |
| Monsoon GDD | 1272.02 | 1183.07 | 409.96 | 0 | 1815.29 | 178 |
| Cooling Degree Days | 4.46 | 148.91 | 470.25 | 0 | 4042.55 | 178 |
| VDC area in $km^2$ | 25.95 | 44.31 | 83.33 | 2.36 | 815.01 | 178 |
| Village # HH. | 945.5 | 1148.89 | 784.75 | 240 | 4692 | 178 |

Descriptive statistics for the repeated cross-sections of NLSS in rural villages.

Table 2.15 – Village median collection time

| | Median village collection time in hours per bhari | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| LAI winter average$_{t-1}$ | -0.0586$^{***}$ | -0.0364 | -0.0386 | | | |
| | (-2.64) | (-1.43) | (-1.49) | | | |
| FPAR winter average$_{t-1}$ | | | | -0.0359$^{***}$ | -0.0255 | -0.0269$^{*}$ |
| | | | | (-3.39) | (-1.56) | (-1.67) |
| % of Vil. area in FUG | | 1.458$^{***}$ | 1.306$^{**}$ | | 1.467$^{***}$ | 1.323$^{**}$ |
| | | (2.71) | (2.43) | | (2.74) | (2.48) |
| Med. time to road | | -0.00126 | 0.000958 | | -0.00129 | 0.00103 |
| | | (-0.11) | (0.08) | | (-0.11) | (0.09) |
| # killings 20km ar. | | 0.00197$^{*}$ | 0.00150 | | 0.00208$^{*}$ | 0.00162 |
| | | (1.76) | (1.32) | | (1.87) | (1.41) |
| Vil. elevation: mean | | 0.000165 | 0.000173 | | 0.000151 | 0.000152 |
| | | (0.52) | (0.57) | | (0.48) | (0.49) |
| Vil. elevation: std. dev. | | 0.00225$^{***}$ | 0.00233$^{***}$ | | 0.00228$^{***}$ | 0.00238$^{***}$ |
| | | (3.75) | (3.71) | | (3.82) | (3.84) |
| Vil. snow cover | | -10.61 | -11.63 | | -15.72 | -16.72 |
| | | (-0.27) | (-0.29) | | (-0.39) | (-0.41) |
| Rainfall z-score | | -0.175 | -0.177 | | -0.176 | -0.178 |
| | | (-1.54) | (-1.55) | | (-1.53) | (-1.54) |
| Monsoon GDD | | 0.000234 | 0.000173 | | 0.000264 | 0.000188 |
| | | (0.52) | (0.40) | | (0.59) | (0.43) |
| Cooling Degree Days | | -0.0000833 | -0.000120 | | -0.000116 | -0.000164 |
| | | (-0.13) | (-0.18) | | (-0.18) | (-0.24) |
| Livestock density | | | -0.00121 | | | -0.00116 |
| | | | (-0.62) | | | (-0.59) |
| Farm land density | | | -0.00400 | | | -0.00415 |
| | | | (-0.85) | | | (-0.87) |
| Population density | | | 0.00163$^{**}$ | | | 0.00170$^{**}$ |
| | | | (1.99) | | | (2.07) |
| Prop. child. density | | | -0.000523 | | | -0.000244 |
| | | | (-0.06) | | | (-0.03) |
| Education density | | | -0.00140$^{**}$ | | | -0.00142$^{**}$ |
| | | | (-2.06) | | | (-2.09) |
| Non-farm business density | | | 0.00207 | | | 0.00194 |
| | | | (0.39) | | | (0.37) |
| Out-migrant density | | | 0.00776$^{***}$ | | | 0.00773$^{***}$ |
| | | | (2.60) | | | (2.60) |
| Year fixed-effect | Yes | Yes | Yes | Yes | Yes | Yes |
| Belt-Zone fixed-effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 301 | 301 | 301 | 301 | 301 | 301 |

Standard errors robust to heteroskedasticity – $t$-statistics in parentheses, $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 2.16 – Firewood collection

| | Household firewood collection in number of bharis per year | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| LAI winter average$_{t-1}$ | 0.351 | 0.586$^{**}$ | 0.455 | | | |
| | (1.46) | (2.11) | (1.62) | | | |
| FPAR winter average$_{t-1}$ | | | | -0.00235 | 0.217 | 0.129 |
| | | | | (-0.02) | (1.12) | (0.65) |
| Med. collection time | | | -3.434$^{***}$ | | | -3.512$^{***}$ |
| | | | (-4.37) | | | (-4.47) |
| Big livestock | 2.980$^{***}$ | 2.823$^{***}$ | 2.824$^{***}$ | 2.992$^{***}$ | 2.830$^{***}$ | 2.832$^{***}$ |
| | (6.99) | (6.52) | (6.54) | (7.01) | (6.53) | (6.56) |
| Land owned, ha | 4.667$^{***}$ | 4.260$^{***}$ | 4.007$^{**}$ | 4.661$^{***}$ | 4.307$^{***}$ | 4.042$^{**}$ |
| | (2.95) | (2.66) | (2.49) | (2.94) | (2.68) | (2.51) |
| Household size | 6.363$^{***}$ | 6.520$^{***}$ | 6.546$^{***}$ | 6.373$^{***}$ | 6.523$^{***}$ | 6.548$^{***}$ |
| | (11.98) | (12.28) | (12.38) | (11.98) | (12.28) | (12.38) |
| Prop. children | -2.308 | -3.234 | -3.291 | -2.172 | -3.134 | -3.181 |
| | (-0.56) | (-0.78) | (-0.80) | (-0.52) | (-0.75) | (-0.77) |
| Avg. education | -2.233$^{***}$ | -2.083$^{***}$ | -2.177$^{***}$ | -2.235$^{***}$ | -2.110$^{***}$ | -2.203$^{***}$ |
| | (-6.99) | (-6.40) | (-6.70) | (-6.98) | (-6.48) | (-6.78) |
| = 1 if NFBus | -6.411$^{***}$ | -6.469$^{***}$ | -6.417$^{***}$ | -6.465$^{***}$ | -6.428$^{***}$ | -6.386$^{***}$ |
| | (-3.04) | (-3.03) | (-3.01) | (-3.06) | (-3.01) | (-2.99) |
| # Migrants | -1.271 | -1.145 | -1.037 | -1.216 | -1.143 | -1.035 |
| | (-1.31) | (-1.18) | (-1.07) | (-1.25) | (-1.18) | (-1.07) |
| % of Vil. area in FUG | | -16.09$^{***}$ | -11.84$^{*}$ | | -15.77$^{***}$ | -11.41$^{*}$ |
| | | (-2.62) | (-1.89) | | (-2.58) | (-1.83) |
| Med. time to road | | -0.229$^{*}$ | -0.213$^{*}$ | | -0.232$^{*}$ | -0.215$^{*}$ |
| | | (-1.83) | (-1.69) | | (-1.84) | (-1.70) |
| # killings 20km ar. | | 0.000186 | 0.00618 | | -0.000671 | 0.00582 |
| | | (0.01) | (0.43) | | (-0.05) | (0.41) |
| Vil. snow cover | | 70.76 | 97.42 | | 97.53 | 107.1 |
| | | (0.12) | (0.17) | | (0.16) | (0.18) |
| Rainfall z-score | | -0.287 | -0.920 | | -0.0539 | -0.706 |
| | | (-0.17) | (-0.54) | | (-0.03) | (-0.41) |
| Monsoon GDD | | -0.0166$^{***}$ | -0.0179$^{***}$ | | -0.0168$^{***}$ | -0.0181$^{***}$ |
| | | (-4.17) | (-4.51) | | (-4.26) | (-4.58) |
| Cooling Degree Days | | -0.00559 | -0.00516 | | -0.00594 | -0.00560 |
| | | (-0.55) | (-0.51) | | (-0.59) | (-0.56) |
| Year fixed-effect | Yes | Yes | Yes | Yes | Yes | Yes |
| Belt-Zone fixed-effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 3590 | 3590 | 3590 | 3590 | 3590 | 3590 |

Standard errors clustered at the village level – $t$-statistics in parentheses, $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 2.17 – Degradation of forest and firewood collections

| | Δ LAI winter average | | | Δ FPAR winter average | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Collection densities | -0.0000344 | -0.0000570$^{**}$ | -0.0000519 | -0.0000512 | -0.000122$^{**}$ | -0.000128$^{*}$ |
| | (-1.53) | (-2.25) | (-1.38) | (-0.91) | (-2.10) | (-1.68) |
| LAI winter average$_{t-1}$ | -0.0513$^{**}$ | -0.0642$^{**}$ | | | | |
| | (-2.41) | (-2.52) | | | | |
| LAI winter average$_{t-2}$ | | | -0.142$^{***}$ | | | |
| | | | (-4.68) | | | |
| FPAR winter average$_{t-1}$ | | | | -0.0618$^{***}$ | -0.130$^{***}$ | |
| | | | | (-2.67) | (-4.01) | |
| FPAR winter average$_{t-2}$ | | | | | | -0.291$^{***}$ |
| | | | | | | (-7.43) |
| % of Vil. area in FUG | | 0.437 | 0.664 | | 0.261 | 0.783 |
| | | (0.88) | (1.01) | | (0.27) | (0.65) |
| Med. time to road | | -0.0142 | -0.0336$^{***}$ | | -0.0342$^{*}$ | -0.0612$^{**}$ |
| | | (-1.65) | (-2.69) | | (-1.80) | (-2.33) |
| # killings 20km ar. | | -0.000265 | 0.000694 | | -0.000509 | 0.00155 |
| | | (-0.32) | (0.57) | | (-0.30) | (0.67) |
| Vil. elevation: mean | | -0.000247 | -0.000409 | | -0.00119$^{**}$ | -0.00183$^{**}$ |
| | | (-0.82) | (-1.09) | | (-2.05) | (-2.50) |
| Vil. elevation: std. dev. | | -0.000529 | 0.000126 | | -0.000612 | 0.000969 |
| | | (-0.85) | (0.15) | | (-0.45) | (0.52) |
| Vil. snow cover | | 18.64 | 82.59 | | 53.07 | 91.31 |
| | | (0.41) | (1.26) | | (0.55) | (0.66) |
| Rainfall z-score | | -0.142 | -0.212 | | -0.255 | -0.404 |
| | | (-1.18) | (-1.22) | | (-1.09) | (-1.20) |
| Monsoon GDD | | -0.000357 | -0.00118$^{*}$ | | -0.00107 | -0.00266$^{**}$ |
| | | (-0.73) | (-1.87) | | (-1.05) | (-2.11) |
| Cooling Degree Days | | -0.0000761 | -0.00158 | | -0.000903 | -0.00360 |
| | | (-0.11) | (-1.50) | | (-0.59) | (-1.61) |
| Year fixed-effect | Yes | Yes | Yes | Yes | Yes | Yes |
| Belt-Zone fixed-effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 301 | 301 | 301 | 301 | 301 | 301 |

Standard errors robust to heteroskedasticity – $t$-statistics in parentheses, $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 2.18 – Engel curves and occupational pattern: fuel expenditures

| | (1) exp. fuel | (2) exp. fuel | (3) exp. fuel | (4) exp. fuel | (5) exp. fuel | (6) exp. fuel |
|---|---|---|---|---|---|---|
| Consumption exp. | 3.805 | -1.233 | -7.440 | | | |
| | (0.44) | (-0.12) | (-0.82) | | | |
| Consumption exp.$^2$ | 0.00944 | 0.0388 | 0.0509 | | | |
| | (0.33) | (1.01) | (1.65) | | | |
| Prop. agri. worktime | -1669.7$^{**}$ | -2375.3$^{**}$ | -2108.5$^{**}$ | | | |
| | (-2.03) | (-2.07) | (-2.23) | | | |
| Med. collection time | | 408.8 | 7.027 | | 348.8 | -62.46 |
| | | (1.01) | (0.03) | | (0.86) | (-0.24) |
| % of Vil. area in FUG | | | -3479.4 | | | -4605.9 |
| | | | (-0.54) | | | (-0.76) |
| Med. time to road | | | 145.2$^{*}$ | | | 171.7$^{**}$ |
| | | | (1.82) | | | (2.25) |
| # killings 20km ar. | | | 2.786 | | | 3.327 |
| | | | (0.34) | | | (0.38) |
| Vil. snow cover | | | -428559.3$^{**}$ | | | -498498.1$^{**}$ |
| | | | (-2.19) | | | (-2.45) |
| Rainfall z-score | | | 88.55 | | | 156.3 |
| | | | (0.25) | | | (0.44) |
| Monsoon GDD | | | 3.862 | | | 4.633 |
| | | | (1.28) | | | (1.42) |
| Cooling Degree Days | | | -1.460 | | | -0.405 |
| | | | (-0.43) | | | (-0.11) |
| Big livestock | | | | -39.43 | -36.57 | -54.01 |
| | | | | (-0.46) | (-0.44) | (-0.65) |
| Land owned, ha | | | | -389.2$^{**}$ | -366.4$^{*}$ | -454.7$^{***}$ |
| | | | | (-2.19) | (-1.93) | (-3.21) |
| Household size | | | | 362.7$^{*}$ | 338.8$^{*}$ | 325.6$^{*}$ |
| | | | | (1.83) | (1.76) | (1.92) |
| Prop. children | | | | -842.8 | -707.7 | -1172.7 |
| | | | | (-0.61) | (-0.50) | (-0.90) |
| Avg. education | | | | -271.4 | -264.1 | -274.6 |
| | | | | (-1.18) | (-1.20) | (-1.35) |
| = 1 if NFBus | | | | -265.2 | -259.7 | -268.7 |
| | | | | (-0.68) | (-0.62) | (-0.64) |
| # Migrants | | | | 107.3 | 47.63 | 69.21 |
| | | | | (0.73) | (0.30) | (0.41) |
| Year F.E. | Yes | Yes | Yes | Yes | Yes | Yes |
| Household F.E. | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 764 | 764 | 764 | 764 | 764 | 764 |

Standard errors clustered at the village level, $t$-statistics in parentheses, $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

### 2.7.2 Description of variables

This paper uses a broad range of village level variables using remote sensing technology. This appendix aims at describing data sources, characteristics and treatment.

#### Biomass measures

The leaf area index (LAI) is a unitless ratio of the leaf area covering a unit of ground area. The measure of leaf area is adapted for the type of vegetation and takes into account the difference between leaves and needles. It is a good proxy of canopy cover, which is especially relevant in our context since fuelwood is often collected by lopping branches (Baland et al., 2010a). On top of being relevant for firewood collection, it is also relevant for biomass production since the canopy cover is one of the determinant of carbon storage in the woody biomass. To construct our variable, we use the MOD15A2 product. This product, distributed by the NASA using measures of the Moderate-Resolution Imaging Spectroradiometer (MODIS) sensor on-board of the Terra satellite, is a eight-day measure of the LAI for every $1km \times 1km$ pixel. For every date of production, we first compute the average LAI for each Nepali village based on a central bureau of statistics shape file. For the main regression, we use the $90^th$ percentile within the last twelve months before the survey as a measure of the current LAI. We opt for the $90^th$ percentile to proxy the canopy cover peak in the last twelve months while limiting measurement errors. Another measure used in the appendix is the average LAI in November and December preceding the survey. This measure intends to focus on two months where the sky generally is clear and deciduous trees still have their leaves.

The Fraction of Absorbed Photosynthetically Active Radiation (FPAR) measures the share of radiation that a plant absorb for photosynthesis. The closer to one is the ratio, the highest the share of radiation in the 0.4-0.7nm spectral range absorbed by the vegetation for photosynthesis and therefore for growth. This information is also provided by the NASA in the MOD15A2 product. For our analysis, we process the FPAR variables in the same way than the LAI variables.

The Normalized Difference Vegetation Index (NDVI) is the third important variable capturing biomass in our study. This index is define between -1 and 1, with larger values indicating more vegetation. It is computed as the ratio $\frac{\text{Near Infra Red} - \text{Visible Red}}{\text{Near Infra Red} + \text{Visible Red}}$. A pixel covered by a dense forest would not reflect any visible red and the ratio would be close to one. To construct our variable, we use the MOD13A2 product distributed by the NASA on a 16-day basis for every $250m \times 250m$ pixel. The variable we use in regressions is the village average of the each pixel maximum over last November and December. This procedure is consistent with the NASA production algorithm which minimizes measurement by picking the maximum of each pixel over 16 days to construct the bi-monthly measure.

Within the three variables, the LAI is the best proxy of the canopy cover. The correlation between LAI on one hand and FPAR and NDVI on the other is relatively high but not perfect. FPAR and NDVI saturate more rapidly in relatively green environment (Myneni et al., 2002). For most of our villages, values of FPAR and NDVI are in the saturation range while LAI varies more. FPAR and NDVI are highly correlated. FPAR takes into account the whole range of photosynthetically active radiation while NDVI is based only on visible red and infra red. FPAR is therefore computationally more intensive. NDVI has already been used in previous studies in economics. In this study, we focus on NDVI in November and December to avoid the monsoon greening which is also affected by crops and grass. November corresponds to the beginning of harvest, a period in which grass and crops are less green while trees still have their leaves. November and December are also cloud free month in Nepal which minimize measurement errors.

#### Additional variables

We also use a broad set of environmental controls derived from satellite imagery. We retrieve information on snow cover, temperatures and altitude from the NASA, through the related MOD10A2, MOD11A2 and ASTER GDEM products. Snow cover is then computed as the share of village area covered by snow during 12 months before the survey. Temperature data allows us to construct a correlate of biomass growth, namely the Growing Degree Days during the monsoon and a correlate of fuel demand, namely the Cooling Degree Days (also named heating degree days in the literature) over last year. Measures of altitude are standards. Rainfall information were computed based the Tropical Rainfall Measurement Mission (TRMM) dataset, the space standard for measuring precipitation over the last 17 years.

Chapter 3

# Success and Failure of Communities Managing Natural Resources: Static and Dynamic Inefficiencies

François Libois

**Abstract** [1]

This paper presents an analytical framework to understand why some communities successfully manage their renewable natural resources and some fail to do it. We develop a N-players, two-period non-cooperative game where a community can impose some exogenous amount of sanctions. We first show that rules preventing dynamic inefficiencies may exist even though static inefficiencies still remain. Second, an increase in the initial value of the resource may lower the utility of all users. The model develops a nuanced view on Ostrom conjecture stating that conservation is harder to implement than sharing.

*Keywords:*
Common-pool resource ; Renewable resource ; Conservation ;
Sanctions ; Institutions

*JEL Classification*:
Q2, O13 , D02 , D23, P48

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*What makes the problem [of free-riding] more difficult in a CPR situation than in a public-goods situation is that unless appropriation problems are resolved, the provision problems may prove intractable.*

Elinor Ostrom, 1990, *Governing the Commons*

## 3.1 Introduction

Traditional societies are often depicted as smart managers of their environment when modern institutions would tend to overuse or even deplete natural resources. Combined with a growing awareness of environmental issues, this vision frequently supports plans to hand over natural resource management to local communities. Nonetheless, this romantic view should be taken up with caution. Although long-enduring societies have most probably found ways to match their living standards to the available resources, they are not *per se* efficient resource managers. For instance, Diamond (2005) argues that full deforestation of Easter Island has lead to a collapse of a civilization. This example is clearly far away from sustainable development.

When population density is increasing, and natural resources are becoming scarcer relatively to the size of the population, common-pool resources (CPR) use has to be, in some way, restricted (Hardin, 1968). There is now a large consensus over the potential ability of communities to overcome the tragedy of the commons (Ostrom, 1990). In general successful communities somehow craft rules of resource use and preservation, implement them and sanction non-compliers. On the other hand, failure of management is often imputed to a lack of information on the state and the dynamic of the resource by the communities at stake [2]. We want to focus on the former and abstract from the latter. Indeed, information on resource flows becomes more and more widespread without necessarily ensuring resource preservation [3]

This paper builds a N-players and two-period model of a renewable and exhaustible resource extraction to analyse the following conjecture: Ostrom (1990, p. 31) says that in a CPR it is easier to solve the within period distributional is-

2. Members of traditional societies are assumed to *'share a magical pre-rationalist view of the world'*. Actually, they consider the flow of resources as determined by some supranatural agencies when their own actions would be irrelevant to explain fluctuations of the flow (Baland and Platteau, 1996, p. 211)

3. Readers interested by the exploitation of common-property resources under uncertainty can, for instance, refer to Antoniadou et al. (2013). Kapaun and Quaas (2013) extensively discuss the optimal fishing strategy with uncertainty on the growth rate through fish life cycle.

sue than the between period conservation problem [4]. Our model therefore incorporate both static and dynamic inefficiencies. Static inefficiencies refer to an excessive amount of effort exerted within a time period in the aim of appropriating a resource. Dynamic inefficiencies refer to an excessive amount of effort in one time period which prevent the resource to grow until the next period. The model is the first to our knowledge to explicitly incorporate dynamic and static inefficiencies in a regulated CPR context.

Based on this model, we first show that increases in the growth rate of the resource lower incentives to harvest the resource in the first period and facilitates resource conservation. For a large enough growth rate, conservation of the resource becomes the payoff dominant strategy. With moderate growth rate, conservation is not feasible in the absence of exogenous sanctions or reputation building mechanism. The extraction of the resource with the optimal amount of effort also requires such mechanisms. This is true in the model but also in framed field experiments (see e.g. the trout fishing experiment described by Noussair et al. (2015)).

We then introduce limited sanctions and show that conservation of the resource between the two periods can be achieved while the players still engage into wasteful competition in the last period, which clearly violates Ostrom's conjecture. The violation of the conjecture happens with a relatively small number of players, a large enough growth rate and a moderate extraction cost. This suggests that Ostrom conjecture especially applies to large communities with slow growing resources which are relatively costly to harvest. It may explain why Huang and Smith (2014) observed closing days on shrimp fisheries but no regulation preventing congestion in the fishing season, for example by limiting the number of fishing vessels.

Finally, the comparative statics exercise rationalizes the decision of leaders managing community forest user groups observed in Rajasthan, India. Indeed, they prefer to plant mango and bamboo trees over teak. Teak has a much higher value than the former species but is not planted on community land while often observed on private lands close to owners' dwellings. We show that, under limited sanctions, a resource with a higher initial value or a larger growth rate does not necessary improve players

4. Ostrom is not the sole author raising this point. Baland and Platteau (1996, p. 232) frame it as a question: *[If] traditional rural societies were apparently able, at least in certain circumstances, to make effective collective arrangements to solve distributive problems, why should they then have been less efficient in organizing to prevent depletion/degradation of common-pooled resources?*

welfare and can even decrease their equilibrium payoffs.

The remaining part of the paper is organized in three sections. The second section gives empirical and theoretical foundations to the model of the third sections. The last section concludes.

## 3.2 Related literature and empirical foundations

Since Gordon (1954) and Hardin's tragedy of the commons (1968), it is well-known in the literature that rational users of common pool resources (CPR) tend to over-exploit them. Their argument mostly remains static, without focusing much on resource conservation and future yields. The analysis of the Great Cod War in Levhari and Mirman (1980) introduces dynamic inefficiencies on top of the static over-fishing problem. Hence, the same Cournot-Nash equilibrium repeats over time and is only affected by the size of the fish stock. There is no discussion of institutional arrangement to escape the bad equilibrium. Brander and Taylor (1998) later use the classical Malthusian argument to explain CPR failure in Easter Island, mostly based on the low growth rate of palm trees on these islands compared to other Polynesian islands. Authors however acknowledge that institutional variations within Polynesia might also explain the collapse of Easter Island. One possible change is to convert unregulated common properties into private resources. This is however not necessarily beneficial for users (Baland and Bjorvatn, 2013) and sometimes imply violence (Sekeris, 2014).

Our focus the introduction of exogenous sanctions in an unregulated common property. We therefore analyse a regulated common property, as defined in Baland and Platteau (1996) and characterize conditions under which rules and associated sanctions are sufficient to modify users behaviour. A first layer of rules addresses *'appropriation problems'* by avoiding rent dissipation and reducing conflicts between appropriators (Ostrom, 1990). For instance, rotation systems are largely used to regulate access to scarce resources. (Arnold and Campbell, 1986, p 436) describes *"systems of spatial control"* of access to resources ensuring an equal access for all to both the nearby and the distant areas.

A second level of rules tackles *'provision problems'* and reduce the effect of today extraction on tomorrow harvest (Ostrom, 1990). Based on case studies in Uttarakhand, India, Agrawal (1994) describes systems in rural communities where *'villagers who designed rules have attempted to match regeneration levels and withdraws by assessing fodder growth during the year, fixing extraction levels below the annual regeneration, and metering fodder extraction using simple measures'*. An institution - called panchayat - delegates officials to assess that fodder extraction remain below the threshold determined ex-ante. Fines can eventually be levied on deviating extractors (Agrawal, 1994, p 272).

It should well be noticed that the existence of one type of rule does not necessarily involves the existence of the other (Baland and Platteau, 1996, p 210). In the same study in Uttarakhand, Agrawal (1994) found also villages *'where panchayats have not designed rules to match withdrawn [with] regeneration'*. In two forest villages from the six analysed, grass is sold through auctions. The successful bidder has little incentives to hold extracted quantities down. He can cut the grass so close to the ground that he damages the roots and harms next year harvest (Agrawal, 1994, p 272). In this case, even if appropriation rules are designed, little concern is set on provision rules.

The opposite case is also depicted in the literature, like in North Carolina where rules on net size, gear type and fishing seasons - partially - prevent to exhaust shrimp stocks but where the industry would be better off by reducing its total number of vessels on the water.

Different modelling options have been used to bring rules in CPR extraction games with static and dynamic inefficiencies. The setup of our model is close to the approach of Sethi and Somanathan (1996). They however tilt their analyses in the direction of evolutionary game theory to analyse the evolution of the proportion of cooperative and self-interested behaviour in a population. They further develop their argument by including reciprocity in a later paper (Sethi and Somanathan, 2006). We prefer to stick to self-interested harvesters and assume an exogenous leader. Our approach then follows the description of motivated leaders of forest users groups in Ethiopia who do not need to be incentivized to sanction non desirable behaviours (Kosfeld and Rustagi, 2015). However, while they empirically analyse the characteristics of leaders successfully managing an homogeneous resource, we collapse leaders ability in one parameter. By doing so, we focus on resource characteristics and analyse how they shape incentives of users, and therefore determine sanctions requirements.

## 3.3 The model

In this section we present the model and its comparative statics. The one-period set-up of the model is standard in the common-pool resource literature (Sethi and Somanathan, 1996; Chung, 1996; Kotchen and Salant, 2011). We extend it to a two-period model with external enforcement. The model can be applied to any exhaustible resource which total value changes over time. For the clarity of exposure and without loss of generality, we frame it as a timber harvest problem.

### 3.3.1 Model setup

$N$ identical, risk-neutral and perfectly informed woodcutters can log trees in a forest of size $F_t$ at time $t$. The initial forest stock is strictly positive, i.e. $F_1 > 0$. Within each time period, woodcutters simultaneously play. The game lasts two periods [5]. At the end of the first period, total harvested quantities $H_1$ are subtracted from the initial stock. The remaining stock $F_1 - H_1$ grows at rate $g$ and we define $G = 1 + g$ for ease of notation [6]. In general, the forest stock at the end of period $t$ is $F_2 = G(F_1 - H_1)$.

Aggregate harvest is the sum of individual harvests $H_t = \sum_{i=1}^{N} h_{it}$. Individual harvest $h$ of player $i$ at time $t$ is a piece-wise linear function of forest stock, own effort $e_i$ and others' effort $e_{-i}$. Effort levels are bounded between 0 and $\bar{e}$, a large enough level of effort which defines a finite action space for each player. The individual harvest function is

$$h_{it} = \begin{cases} e_{it} & \text{if} \quad \sum_{j=1}^{N} e_{jt} < F_t \quad (3.1a) \\ \dfrac{e_{it}}{\sum_{j=1}^{N} e_{jt}} F_t & \text{otherwise} \quad (3.1b) \end{cases}$$

In the first piece of the harvest function (3.1a), woodcutter $i$ harvests a quantity equal to his level of effort. The second piece of the harvest function (3.1b) corresponds to a resource exhaustion situation. If aggregate effort is sufficient to harvest the whole

5. The second period can be interpreted as the second period present value of remaining periods.

6. We assume that the discount factor is equal to 0. Readers interested by this parameter can read the whole model assuming that $G = \frac{(1+g)}{(1+\delta)}$ with $\delta$ the discount factor.

resource, the resource stock is fully depleted and divided among loggers with respect to their relative share of effort [7]. The utility $U_i$ of woodcutter $i$ is linear in both payoff and cost with $0 < c < 1$, the cost of effort [8].

$$U_i(e_{it}, h_{it}(e_{it}, e_{-it}, F_t)) = \sum_{t=1}^{2} (h_{it} - ce_{it}) \tag{3.2}$$

At any point in time and conditionally on harvesting the whole resource, the efficient level of aggregate effort is such that $\sum_{j=1}^{N} e_{jt} = F_t$. Woodcutters put just enough effort to deplete the forest. They generate an aggregate payoff equal to $(1-c)F_t$. If $G > 1$, the size of the forest grows over time and it is straightforward to show that the social optimum of the game is to efficiently deplete the forest in the last period. It is achieved with effort levels equal to $e_{j1} = 0$ and $\sum_{j=1}^{N} e_{j2} = GF_1$. It yields an aggregate payoff equal to $(1-c)GF_1$. [9]

### 3.3.2 Nash equilibrium

In an open-access setting with simultaneous moves, each player maximizes one's utility, taking others' effort as given. The game is solved by backward induction. In period two, we know from (3.1a) that woodcutters harvest the forest since $c < 1$, and thus $\sum_{j=1}^{N} e_{j2} \geq F_2$. Considering the second piece of the harvest function (3.1b), there is one maximization problem for each player:

$$\max_{e_{i2}} \quad u_{i2} \quad = \quad \max_{e_{i2}} \quad \frac{e_{i2}}{\sum_{j=1}^{N} e_{j2}} F_2 - ce_{i2} \tag{3.3}$$

Each maximization problem yields one first order condition:

$$\frac{\partial u_{i2}}{\partial e_{i2}} = \frac{\sum_{j \neq i}^{N} e_{j2}}{(\sum_{j=1}^{N} e_{j2})^2} F_2 - c = 0 \tag{3.4}$$

By symmetry, it is easy to show that $e_{i2} = e_{j2}$ for $\forall i, j$ and for the sake of simplicity, we drop the individual index.

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7. Notice that the first piece of the harvest function can be interpreted as the slope of a strictly monotonic increasing and concave harvest function at the exhaustion point.

8. $c \geq 1$ is a trivial problem where resource extraction does not strictly increase players' utility.

9. If $G \leq 1$, i.e. the value of the resource decreases over time, socially optimal extraction happens in the first period with effort level $\sum_{j=1}^{N} e_{j1} = F_1$ and $e_{j2} = 0$. It generates an aggregate payoff equal to $(1-c)F_1$.

$$\frac{(N-1)e}{N^2e^2}F_2 = c \quad \Rightarrow \quad e = \frac{(N-1)}{cN^2}F_2 \tag{3.5}$$

To remain with an interior solution on (3.1b), we need $Ne \leq F_2$ which is verified iff $c < \frac{N-1}{N}$, or equivalently iff $1-c > \frac{1}{N}$. We further work with this additional restriction in the range of $c$. Given the second period subgame perfect Nash equilibrium, each player second period utility is given by the expression:

$$u_2 = \frac{1}{N}F_2 - \frac{N-1}{cN^2}F_2 \quad \Rightarrow \quad u_2 = \frac{1}{N^2}F_2 \tag{3.6}$$

It is suboptimal since $Nu_2 = \frac{F_2}{N} < (1-c)F_2$ if $c < \frac{N-1}{N}$.

In period 1, the maximization problem shrinks to

$$\max_{e_{i1}} \quad U_i \quad = \max_{e_{i1}} \quad u_{i1} + u_{i2} \quad = \quad \max_{e_{i1}} \quad h_{i1} - ce_{i1} + \frac{1}{N^2}G(F_1 - \sum_{j=1}^{N} h_{j1}) \tag{3.7}$$

Combining (3.1a) and (3.7), first period extraction occurs if $G < N^2(1-c)$. It can thus occur although $G > 1$, which is not the socially efficient state. If so, $\sum_{i=1}^{N} e_{i1} \geq F_1$ and (3.1b) is the relevant piece of the extraction function, which corresponds to resource exhaustion. By a similar argument than in the second period subgame, the equilibrium level of effort in the first period is $e_1 = \frac{(N-1)F_1}{N^2c}$. It means that the resource is fully exhausted in the first period and woodcutters achieve a payoff equal to $U_i = \frac{F_1}{N^2}$.

To summarize, if $G < N^2(1-c)$ then the game has one pure Subgame Perfect Nash Equilibrium with realized individual payoff equal to $\frac{F_1}{N^2}$ and associated strategy $e_1 = \frac{(N-1)F_1}{N^2c}$ and $e_2 = 0$. It is a pure prisoners' dilemma. If $G \geq N^2(1-c)$ then the game has one more Subgame Perfect Nash Equilibrium with associated strategy $e_1 = 0$ and $e_2 = \frac{(N-1)GF_1}{N^2c}$. For each player, it yields a payoff equal to $\frac{GF_1}{N^2}$, bearing in mind that $H_1 = 0$, so that $F_2 = GF_1$. This strategy is payoff-dominant while the previous one is risk-dominant. Notice that when $G$ is large the game combines both characteristics of the prisoners' dilemma and of the stag hunt.

### 3.3.3 Static and dynamic inefficiencies

The aggregate payoff differential between the first best and the payoff-dominated Nash equilibrium is equal to $(1-c)GF_1 - \frac{F_1}{N}$. Inefficiencies result both from the absence of resource conservation between periods and from excessive harvesting effort by woodcutters. Two second bests are worth discussing.

First, let us define ***sharing*** as a strategy where all players restrain their effort and share the resource with effort level $\frac{F_t}{N}$, conditionally on others playing $\frac{F_t}{N}$. *Sharing* allows players to extract the resource at one point in time with the efficient level of effort. Compared to *sharing*, the Nash Equilibrium generates aggregate within period inefficiency equal to $(1-c)F_t - \frac{F_t}{N} = (\frac{N-1}{N} - c)F_t > 0$. Sharing in $t$ is however not an equilibrium since the best response to $e_{-it} = \frac{F_t}{N}$ is $e_{it} = \left(\sqrt{\frac{N-1}{Nc}} - \frac{N-1}{N}\right) F_t$ and generates a net additional benefit equal to $\mathbf{d_t} = \omega F_t$, the net deviation payoff from period $t$ *sharing*. $\omega$ therefore represent the net share of the resource value that a player gains when he deviates from *sharing*. The value of $\omega$ is an increasing function of the number of players $N$ and a decreasing function of the cost of effort $c$, with $\omega = \frac{N-1}{N} + c - 2\sqrt{c}\sqrt{\frac{N-1}{N}}$ (shown in the appendix). In Ostrom's terminology $\mathbf{d_t}$ is the source of a typical *appropriation problem* referring to static inefficiencies.

Second, let us define ***conservation*** as a strategy where players refrain from extracting in the first period by playing $e_1 = 0$, conditionally on others exerting no effort at all. *Conservation* means that the forest grows between the two periods. If $G < N^2(1-c)$, this strategy is not necessarily an equilibrium since a deviating player could extract the whole resource on his own in the first period and gain a net deviation payoff from *conservation* equal to $\mathbf{d_c} = (1 - c - \frac{G}{N^2})F_1$ (proof in the appendix[10]. By extracting the resource in the first period, players forego a higher second period payoff and generate dynamic inefficiencies. Ostrom refers to inefficiencies related to the inter-temporal evolution of the resource as *provision problems.*

Let us finally define $B$, the set of tuples $(c, N, G)$ for which incentives to deviate from first period sharing and conservation are equal. Any tuple belonging to $B$ is

10. It is obvious that if $G$ is too large given $c$, $\mathbf{d_c}$ can be negative. Or, equivalently, there exist combinations of $c$ and $G$ such that $\mathbf{d_c} < 0$

such that $d_1 = d_c$, or more formally

$$B = \left\{ (c, N, G) : G = \omega N^2, \quad 0 < c < \frac{N-1}{N}, \quad N, G \in \mathbf{R}^+ \right\} \tag{3.8}$$

**Proposition 3.1.** *On incentives to deviate from socially desirable strategies:*

1. *if a tuple $(c, n, G)$ belongs to the strict upper(lower)-contour set of $B$, then the net deviation payoff from first period* sharing *is strictly smaller (larger) than the net deviation payoff from* conservation*, that is $d_1 < d_c$ ($d_1 > d_c$).*
2. *if the growth rate is larger than a threshold, then there is no benefit of deviating from* conservation*. Formally if $G \geq N^2(1-c)$, then $d_c \leq 0 \leq d_1$*

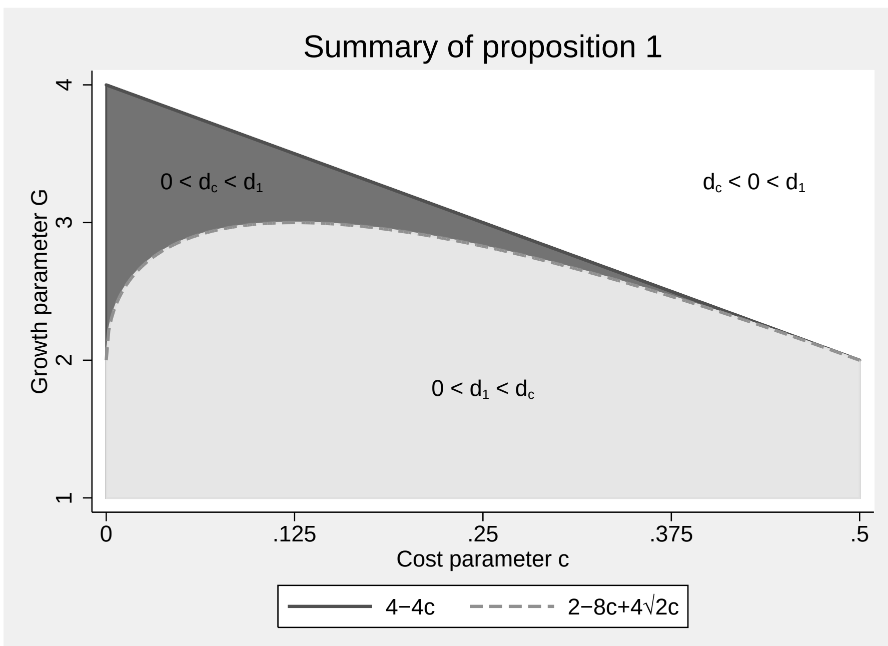


Figure 3.1 – Map of proposition 1

Figure 3.1 maps proposition 3.1 for two players. First, the dashed line maps the contour set $B$ where provision problems are just equal to appropriation problems. Below the dashed line, in the light grey area, players have more incentives to deviate from *conservation* than from *sharing*. Above the dashed line, the growth rate is sufficiently large to reduce incentives to deviate from *conservation* and these incentives become smaller than incentives to deviate from *sharing*. In the white area, deviation from *conservation* is no more beneficial. It corresponds to the second part of proposition 3.1. Future gains are so high that the second period Subgame Perfect Nash Equilibrium payoff is larger than the payoff associated to a monopolistic extraction in the first period. Conservation is a matter of pure coordination. In this case, the first period appropriation problem is not relevant.

### 3.3.4 Governing the commons

In a purely decentralized context, without coordination device nor reputation building mechanisms, there is no way to escape the tragedy of the commons. This is true in theory but also has relevance in the field as shown in (Noussair et al., 2015). However, as put forward by Ostrom (1990), Baland and Platteau (1996) and others, communities are able to design rules, monitor individual actions and impose sanctions to members who deviate from a given behaviour.

We define the conditional sanction $\sigma_s$ as a direct payoff loss incurred by any player deviating from strategy $s$. $\sigma_s$ is the minimal level of conditional sanctions required such that $s$ is a credible strategy, that is $\sigma_s$ is sufficient to deter any player from deviating from the strategy $s$. Sanctions in a given game are bounded such that $0 \leq \sigma \leq \bar{\sigma}$. $\bar{\sigma}$ is predetermined and does not change during the game[11]. It refers to the monitoring and sanctioning technology available in the community[12]. We define a rule $\mathcal{R}$ as a strategy $s$ and an associated conditional sanction $\sigma_s$. A rule $\mathcal{R}\{s;\sigma_s\}$ is feasible if $\sigma_s \leq \bar{\sigma}$. For the sake of simplicity, we represent the community by a benevolent planner which sets rules, monitor actions and eventually impose sanctions.

From proposition 3.1, we know that the maximal benefit of deviating from first period sharing is $d_1$. Therefore, $\mathcal{R}_1 = \left\{s_1 \equiv \left[e_1 = \frac{F_1}{N}, e_2 = 0\right]; \sigma_{s_1} = d_1\right\}$ implements first period sharing.

Assuming a Nash solution in the second period, the maximal benefit of deviating from conservation is $d_c$ and $\mathcal{R}_c = \left\{s_c \equiv \left[e_1 = 0, e_2 = \frac{GF_1}{N^2c}\right]; \sigma_{s_c} = d_c\right\}$ implements conservation.

11. We assume $\bar{\sigma}$ as predetermined level of effective sanctions since norms often evolve a a slower pace then the environment.

12. $\bar{\sigma}$ can be low if outside valuable options exist, while it can be very high if exclusion from the group is very costly or if breaking the rule fills the offender with infinite remorse and regrets. Readers interested in imperfect monitoring can read $\bar{\sigma}$ as the expected sanctions in a game with risk-neutral agents.

**Corollary 3.1.** *On Ostrom conjecture:*

*If $\bar{\sigma} > \sigma_{s_2}$, then Ostrom conjecture does not hold in the upper-contour set of $B$ and is weakly valid otherwise.*

This corollary states that, for any tuple in the upper-contour set of $B$, it is always possible to find a level of sanctions $\sigma < \bar{\sigma}$, such that conservation ($\mathcal{R}_c$) is feasible while first period sharing ($\mathcal{R}_1$) is not. This is true even if second period sharing is not feasible, that is if $\sigma_2 > \bar{\sigma}$.

The general intuition behind this corollary lies in players anticipations of second period gains when they decide on their first period moves. If the growth rate is sufficiently large, second period payoff is big enough to mitigate individual incentives to extract in the first period, even if a player could be the sole first period harvester. Small sanctions are then sufficient to deter strictly positive first period effort levels, even if these sanctions are not sufficient to sustain an efficient extraction when extraction takes place. The violation of Ostrom conjecture is visible at the equilibrium if $d_c < \bar{\sigma} < d_1 \leq d_2$ which corresponds to the dark grey and white areas in figure 3.1. Under this conditions, players conserve the resource between the two periods but play Nash in the second period and therefore put too much effort to harvest the resource. In Ostrom's terminology, the provision problem is fixed but the appropriation problem remains open.

Notice that the parameter space in which Ostrom conjecture holds increases as the number of players goes up. Intuitively, if the number of players is large, the resource must be shared between many and incentives are diluted. First period harvest becomes more and more attractive for any woodcutter if others conserve. On the contrary, for games with few players, static inefficiencies may remain while dynamic inefficiencies would disappear.

To achieve the first best, it is both necessary to deter players from harvesting in the first period and prevent excessive effort in the second period. Conditionally on conservation, $d_2$ is the maximal benefit of deviating from second period sharing. Conditionally on second period sharing, the maximal benefit of deviating from conservation is $d_{c|s2} = (1-c)F_1 - (1-c)\frac{GF_1}{N} = (1-c)(1-\frac{G}{N})F_1$. This value is smaller than $d_c$ because the second period subgame payoff becomes larger. Sanctions have therefore to be higher than the two thresholds to achieve the first best, with associated rule $\mathcal{R}^\star = \left\{s^\star \equiv \left[e_1 = 0, e_2 = \frac{GF_1}{N}\right]; \sigma_{s^\star} = \max(d_{c|s2}, d_2)\right\}$. Notice that it is possible to find $\bar{\sigma}$ such that the first best cannot be implemented, despite being able to share the resource in the second period. It is the case when $d_{c|s2} > d_2$. Written in terms of growth rate, this inequality states that $G < \frac{(1-c)N}{\omega N+1+c}$. In this case, first period sharing is the sole feasible improvement with respect to the Nash outcome. Last, if $\bar{\sigma} > \sigma_{s^\star}$, the violation of Ostrom conjecture is never apparent because *sharing* will always be implemented. However if the growth rate is large enough, second period *sharing* requires more sanctions than *conservation*.

### 3.3.5 Comparative statics

Assuming a given $\bar{\sigma}$, this subsection derives comparative statics for each resource $(G, F_1)$. We first map the different equilibrium strategies, then reinterpret Ostrom conjecture and finally demonstrate that a more valuable resource does not necessary imply a higher payoff for harvesters.

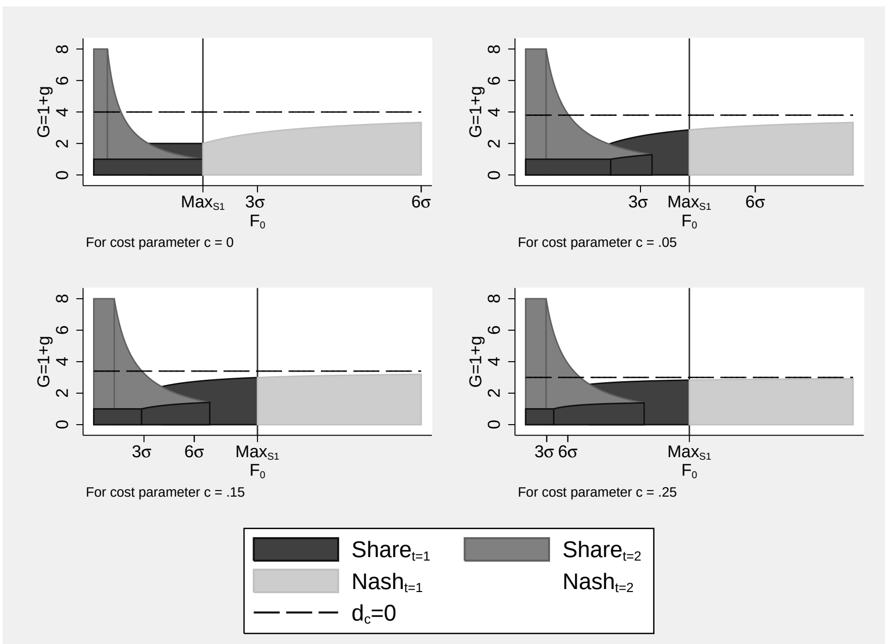


Figure 3.2 – Equilibrium strategies with $0 < \bar{\sigma} < \infty$ statics as a function of resource initial value $F_1$ and growth $G$.

Figure 3.2 maps the feasible rule achieving the largest payoff given $\bar{\sigma}$ for every values $F_1$ and growth $G$ of a potential resource. The four graphs correspond to different harvest cost $c$ and the illustration corresponds to a two players game.

By definition, $\mathcal{R}^\star$ always achieves the first best. It is feasible only if $G \leq \frac{\bar{\sigma}}{\omega F_1}$ and $G \geq N - \frac{N\bar{\sigma}}{(1-c)F_1}$. It corresponds to the intermediate grey area in figure 3.2.

First period sharing is feasible as long as $F_1 \leq \frac{\bar{\sigma}}{\omega}$. $\mathcal{R}_1$ is chosen over $\mathcal{R}_c$ if $\frac{(1-c)F_1}{N} > \frac{GF_1}{N^2}$, which yields the condition $G < (1-c)N$. This is the darker grey area in figure 3.2.

Second period Nash is feasible when $G \geq N^2(1 - c - \frac{\bar{\sigma}}{F_1})$ and is chosen as soon as $G \geq (1-c)N$. It matches with resources in the white area of figure 3.2. This area also corresponds to resources for which Ostrom conjecture does not hold or is not precise enough.

The white area is divided in two parts by a dashed line. At $G = N^2(1-c)$ the growth rate is just sufficient to reduce the benefit of deviating from conservation to 0. Above this threshold, sanctions are not necessary to reach the second period extraction subgame and conservation is a matter of pure coordination. Appropriation problems do not have to be solved before tackling the provision problem.

In the white area below the dashed line, sanctions are necessary to prevent first period extraction. Notice that there exist a whole range of resources for which first period sharing is feasible but is not chosen. For all values $F_1 \leq \frac{\bar{\sigma}}{\omega}$, $\mathcal{R}_1$ is feasible but, in the white area, conservation yields a higher payoff than first period sharing. Anyway, $\mathcal{R}_1$ is no more feasible if the initial value of the resource lies above the last threshold. Despite this impossibility, the existence of sanctions allow resource conservation in the white area. It means that sanctions prevent dynamic inefficiencies while static inefficiencies remain. This is a clear violation of Ostrom conjecture.

Figure 3.2 also emphasize the role of $c$. A larger cost $c$ raises the marginal cost of the appropriation effort and decrease extraction benefit. Both $\mathcal{R}_1$ and $\mathcal{R}_2$ require less sanctions. Increasing the number of players has similar consequences. It has no effect on the cost of appropriation but it lowers the benefit of deviation through the reduction of the initial share for each player in the total effort.

Based on the rule achieving the highest possible payoff for each resource $(G; F_1)$, we derive the following proposition:

**Corollary 3.2.** *More is not always better:*

*If $0 < \bar{\sigma} < \infty$, there always exists some resources $(G; F_1)$ which generate lower payoffs for players than less valuable resources $(G'; F_1')$ with $G' \leq G$ or $F_1' \leq F_1$ and at least one inequality binding.*

*Proof.* Suppose that $\mathcal{R}_1$ is just feasible and achieves the highest feasible payoff for the resource $(G; F_1)$. By definition, it means that $d_1 - \bar{\sigma} = 0$. At this frontier, $F_1 = \frac{\bar{\sigma}}{\omega}$. Since sharing in the first period is just feasible, players' payoff are equal to $u_i^{MaxS1} = \frac{(1-c)\bar{\sigma}}{\omega N}$. Another resource $F_1' = F_1 + \varepsilon$, with $\varepsilon$ strictly positive and small, would not allow the implementation of $\mathcal{R}_1$. First period Nash extraction would be the only possible outcome. Players utility would then be $u_i = \frac{\bar{\sigma}+\varepsilon}{\omega N^2} < u_i^{MaxS1}$. To achieve a larger payoff than $u_i^{MaxS1}$ under first period Nash, the value of the resource has to be at least equal to $F' \geq \frac{N(1-c)\bar{\sigma}}{\omega}$.

$\mathcal{R}_c$ is just feasible if $d_c - \bar{\sigma} = 0$. Rewritten in terms of resource value it yields $F_1 = \frac{\bar{\sigma}}{1-c-\frac{G}{N^2}}$. $F_1$ generates individual payoffs such that $u_i^{Nash2} = \frac{G\bar{\sigma}}{N^2(1-c-\frac{G}{N^2})}$. A slightly more valuable resource $F_1' = F_1 + \varepsilon$ would prevent the implementation of conservation followed by Nash extraction in the second period. Players would then extract in the first period and achieve a strictly lower payoff as long as $F_1' < \frac{G\bar{\sigma}}{1-c-\frac{G}{N^2}}$.

A similar argument can be repeated at the frontier of the first best implementation. At the frontier where $GF_1 = \frac{\bar{\sigma}}{\omega}$, where $\mathcal{R}^\star$ is just feasible, players achieve a maximal feasible payoff $u^\star = \frac{(1-c)\bar{\sigma}}{\omega N}$. At the frontier of the first best implementation, where conservation binds, which is defined by the relation $(1-c)(1-\frac{G}{N})F_1 - \bar{\sigma} = 0$, payoffs are equal to $u^\star = \frac{G\bar{\sigma}}{N-G}$. So, at the first of the two frontiers, players need at least a resource such that $GF_1 \geq \frac{N(1-c)\bar{\sigma}}{\omega}$ if conservation remains feasible and $F_1 > \frac{\bar{\sigma}}{\omega}$ if first period sharing is implemented. At the second frontier, the growth rate is so low that first period sharing is the second best option. Under $\mathcal{R}_1$, a resource of value $F_1 \geq \frac{NG\bar{\sigma}}{(1-c)(N-G)}$ is necessary to yield a payoff at least equal to the highest feasible first best payoff. □

This corollary says that if enforcement is imperfect, a resource which is apparently more valuable can yield a lower utility for harvesters. This is not the case if sanctions do not exist or if they are infinite. Without sanctions, payoffs under Nash always increase as the growth rate $G$ or the initial value of the resource $F_1$ go up. With infinite sanctions, the first best is always implemented and payoffs under the first best always increase in the two arguments.

In the presence of limited enforcement, small increases of the growth rate or of the resource value may lead to switch from one equilibrium to another, less desirable, equilibrium. Small increases in the resource value or growth rate raise incentives to deviate from sharing and conservation by a small margin. Because sanctions are bounded, this might be sufficient to raise the deviation benefit above the value of sanctions and prevent the enforcement of the rule. As a consequence, there is switch from a more desirable to less desirable equilibrium with sanctions and users' payoff decline.

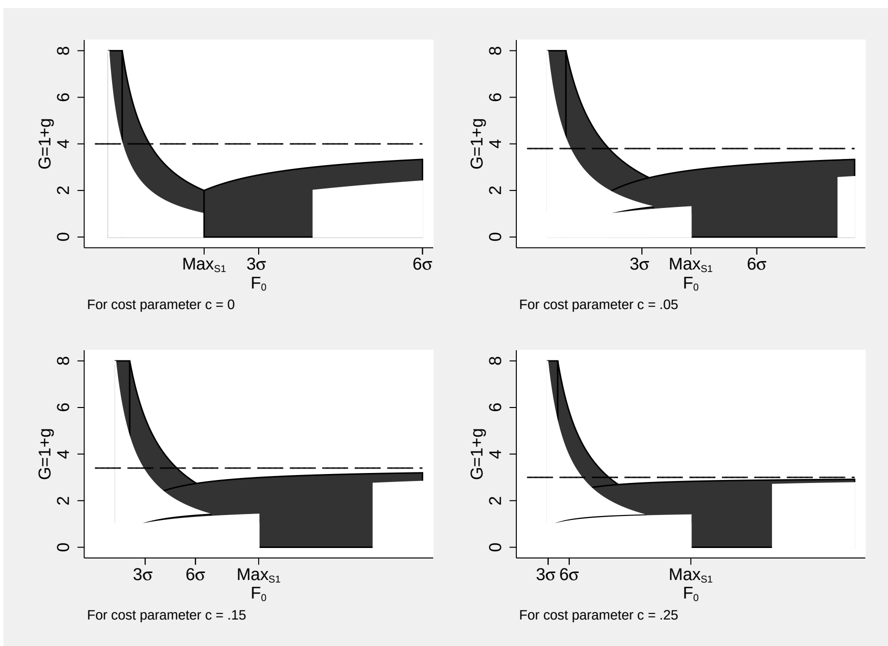


Figure 3.3 – When more can be worse: welfare comparison of equilibrium strategies with limited sanctions.

Figure 3.3 illustrate proposition 3.2. It maps in grey all combinations $(G; F_1)$ which generate individual payoffs lower than another resource $(G'; F_1')$ with $G' \leq G$ or $F_1' \leq F_1$ and at least one inequality binding. The four graphs consider different cost parameters.

### 3.3.6 Discussion

This basic model allows understanding how rules can help a community to overcome the tragedy of the commons in a dynamic setting. First, we show that, as the growth rate of a resource increases, the relative size of incentives to deviate from sharing decreases compared to incentives to deviate from conservation. When the growth rate is large enough, players even do not have any benefit to deviate from conservation. The benefit to deviate from conservation also decreases as the extraction cost goes up since it reduces the value of harvesting. Conservation becomes more difficult as the number of players rises since the value of harvesting with competition in the first period increase.

To escape from the prisoners' dilemma, rules and associated sanctions are necessary. For very large resource growth rates, the only relevant issue is the ability of the community to solve future static inefficiencies, i.e. to prevent non-cooperative extraction in the second period. For intermediate growth rates, we show that it is easier to implement a conservation rule than to immediately share the resource. Dynamic inefficiencies are fully overcome even though static inefficiencies partly remain. For small growth rates, communities with a relatively low ability to implement sanctions can rationally craft rules which lead to a first period sharing equilibrium even if the community is well aware that second period sharing is the social optimum.

The comparative static exercise has broad practical implications. In our model we always consider that the value of the resource and its growth rate are exogenously determined. However, in practice, field observations report that players may have some influence on the initial investment. An anecdotal evidence collected during field visits in Udaipur district, Rajasthan, India, in August 2012 nicely illustrates this point. Some community forest user groups refrain from planting teak despite its very high value and intermediate growth rate. They prefer to plant species like mango or bamboo trees. Group leaders justify their investment decision by their anticipations of members' future behaviour. They point out that the community of users will not be able to prevent its members from felling teak down before it gets mature, precisely because its value is too large. At the opposite, bamboo trees grow faster and have a lower initial value. Rules and associated effective sanctions prevailing in the group are sufficient to deter early logging. It is even more salient with mango trees. Mango timber in itself is not worth a lot. It is then relatively easy to implement conservation and sharing rules of mango fruits, the value of which increases sharply in a short period of time as fruits get mature.

The question is then why, empirically, achieving conservation often appears more difficult than solving the appropriation problem. The role of the number of players, the characteristics of the resource and the cost of extraction explicit appear in the model. Imperfect information is often cited as an argument against conservation. This is true as shown Antoniadou et al. (2013) for instance, however the spread of scientific knowledge decrease the salience of this argument. Higher inequalities may also make conservation more difficult (Dayton-Johnson and Bardhan, 2002) in spite of the mitigating effect of inequalities on static inefficiencies.

On top of these positive implications, the model also provides some normative insights. If more is always better in failed and in highly effective communities, we show that more can be worse in the presence of a moderately effective community. When sanctions are limited, larger resource growth rate or initial value can lead to a change of equilibrium strategies and consequently to a drop of players' utility. The wide-range causes of such changes include natural resource improved management techniques, climate change consequences, new investment possibilities, improved market access, resource booms. The ability to implement sanctions is key to understand that two communities managing the same resource in the same way might react very differently following an increase in the value of the resource. One community can improve its members' livelihoods while in the other, everyone might end up worse off. From a policy perspective, one should take care while designing external interventions. The sole focus on technical solutions might not be sufficient and special caution should also be given to institutional reinforcement.

## 3.4 Conclusion

This article investigates determinants of successful management in a regulated common property, compare to the unregulated case. We construct a N-players, two period non-cooperative game with a growing resource to emphasize the difference between appropriation and preservation issues. Appropriation problems refer to static inefficiency and can be solved by sharing the resource within a time period. Preservation problems tackle the problem of natural resource conservation, closely related to dynamic inefficiencies. As broadly investigated in the literature on rent-seeking, competing players exert excessive effort and generate social waste. We also show that, for low and moderate growth rates, competition lead to dynamic inefficiencies. Players extract too early and prevent themselves to reach a higher second period payoff.

Nevertheless, it appears from field studies that communities are not doomed to mismanage their resources and to fall in the well documented *tragedy of the commons*. Some craft rules, monitor and sanction users. We show that it is not necessarily easier for a community to have credible appropriation rules than to set up preservation rules. For intermediate growth rate and large growth rate our model explains why users may protect a resource until a certain point and then fight to appropriate it.

This paper also stresses that, under imperfect institutions, a more valuable resource can actually decrease players' welfare. This result does not hold in purely decentralized context nor with perfect institutions. It is therefore crucial to correctly understand the ability of a group to solve collective action problems while designing external interventions. Rules may have a limited scope and successful management is also conditional on resource characteristics. Something important to keep in mind, especially when time is needed to achieve changes within institutions.

## 3.5 Appendix

### Proof of Proposition 1

Let's first prove that $\mathbf{d_t} = (\frac{N-1}{N} + c - 2\sqrt{c}\sqrt{\frac{N-1}{N}})F_t$. Suppose that all players but $i$ play $e^\star_{-it} = \frac{F_t}{N}$. The maximization problem of player $i$ becomes

$$\max_{e_{it}} \quad u_{it} \quad = \quad \max_{e_{it}} \quad \frac{e_{it}}{e_{it} + (N-1)e^\star_{-it}} F_t - c e_{it} \tag{3.9}$$

This yields the first order condition for player $i$:

$$\frac{\partial u_{it}}{\partial e_{it}} = \frac{(N-1)e^\star_{-it}}{(e_{it} + (N-1)e^\star_{-it})^2} F_t - c = 0 \tag{3.10}$$

$$\frac{\frac{(N-1)F_t}{N}}{\left[e_{it} + \frac{(N-1)F_t}{N}\right]^2} F_t - c = 0$$

$$\frac{N-1}{cN} F_t^2 = \left[e_{it} + \frac{(N-1)F_t}{N}\right]^2$$

$$\sqrt{\frac{N-1}{cN}} F_t = e_{it} + \frac{(N-1)}{N} F_t$$

$$e_{it} = \left(\sqrt{\frac{N-1}{cN}} - \frac{N-1}{N}\right) F_t \tag{3.11}$$

Knowing the best response of player $i$ to $e^\star_{-it} = \frac{F_t}{N}$, we can compute the highest utility level achievable by a player deviating from sharing:

$$u_{it} = \left[\frac{\sqrt{\frac{N-1}{cN}} - \frac{N-1}{N}}{\sqrt{\frac{N-1}{cN}} - \frac{N-1}{N} + \frac{N-1}{N}} - c\sqrt{\frac{N-1}{cN}} + c\frac{N-1}{N}\right] F_t \tag{3.12}$$

$$u_{it} = \left[\frac{\sqrt{\frac{N-1}{cN}} - \frac{N-1}{N} - c\frac{N-1}{cN} + c\frac{N-1}{N}\sqrt{\frac{N-1}{cN}}}{\sqrt{\frac{N-1}{cN}}}\right] F_t$$

$$u_{it} = \left[1 - 2\frac{N-1}{N}\sqrt{\frac{cN}{N-1}} - c\frac{N-1}{N}\right] F_t$$

$$u_{it} = \left[1 + c\frac{N-1}{N} - 2\sqrt{c}\sqrt{\frac{N-1}{N}}\right] F_t \tag{3.13}$$

To know the net benefit of deviating from *sharing*, the last step is to compare the deviation payoff with the *sharing* payoff.

$$\mathbf{d_t} = \left[1 + c\frac{N-1}{N} - 2\sqrt{c}\sqrt{\frac{N-1}{N}}\right] F_t - (1-c)\frac{F_t}{N} \tag{3.14}$$

$$\mathbf{d_t} = \left[\frac{N + cN - c - 1 + c}{N} - 2\sqrt{c}\sqrt{\frac{N-1}{N}}\right] F_t$$

$$\mathbf{d_t} = \left(\frac{N-1}{N} + c - 2\sqrt{c}\sqrt{\frac{N-1}{N}}\right) F_t \tag{3.15}$$

Let's then prove that $\mathbf{d_c} = \left(1 - c - \frac{G}{N^2}\right) F_1$. Suppose that all players but $i$ do not extract in the first period and play Nash in the second period. They therefore opt for a strategy $\left(e_{-i1} = 0; e_{-i2} = \frac{GF_1}{cN^2}\right)$. Player $i$ first period maximization problem shrinks to

$$\max_{e_{i1}} \quad u_i \quad = \quad \max_{e_{i1}} \quad e_{i1} - ce_{i1} + \frac{G(F_1 - e_{i1})}{N^2} \tag{3.16}$$

It means that $i$ harvests the resource in the first period only if $1 - c - \frac{G}{N^2} > 0$, which can be rewritten as $G < (1-c)N^2$. The net benefit of harvesting in the first period is then equal to the whole surplus that $i$ gets by harvesting the whole resource in the first period minus what $i$ would have received if abstaining from extracting in $t = 1$ and playing Nash in $t = 2$.

$$\mathbf{d_c} = (1-c)F_1 - \frac{GF_1}{N^2} \quad \Longrightarrow \quad \mathbf{d_c} = \left(1 - c - \frac{G}{N^2}\right) F_1 \tag{3.17}$$

It is straightforward to modify the last proof assuming that second period sharing is implemented. The net benefit of harvesting in the the first period is then equal to

$$u_i - u_i^{Share2} = (1-c)F_0 - \frac{(1-c)GF_0}{N} \quad \Longrightarrow \quad \mathbf{d_{c|s_2}} = (1-c)(1-\frac{G}{N})F_1 \quad (3.18)$$

The contour set $B$ is the set of tuples $(c, N, G)$ for which $\mathbf{d_c} = \mathbf{d_1}$. This equality can be written as

$$\left(1 - c - \frac{G}{N^2}\right) F_1 = \left(\frac{N-1}{N} + c - 2\sqrt{c}\sqrt{\frac{N-1}{N}}\right) F_1 \quad (3.19)$$

or, stated in terms of resource growth rate,

$$G = N - 2N^2 c + 2N^2 \sqrt{c}\sqrt{\frac{N-1}{N}} \quad (3.20)$$

Chapter 4

# Encouraging Private Ownership of Public Goods: Theory and Evidence from Belgium

**Gani Aldashev, François Libois, Joaquín Morales and Astrid Similon**

**Abstract** [1]

We study short-run and long-run effects of a government subsidy to private non-profit ownership of public good projects. In a simple model, we show that the subsidy increases the prices of project assets in the short run; however, the effect does not persist and prices decline in the long run. This happens because the subsidy temporarily relaxes the resource constraint of non-profit organizations, which allows them to engage in supply-expanding activities. We test this prediction using a unique dataset that we have constructed from Belgian notarial land-transaction records and exploiting a policy reform in public subsidies for land purchases by non-profits aiming at creating privately-owned natural reserves. Using the MS-estimation method (Maronna and Yohai, 2000) robust to outliers, we also provide a methodological contribution to the analysis of markets with quasi-donations.

*Keywords:*
Non-profit organizations; Public goods; Fundraising; Land markets
Protected areas; Conservation

*JEL Classification*:
L3, Q2, L22, H41, N5

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## 4.1 Introduction

Non-profit organizations are key providers of public goods in modern economies. 67 per cent of in-patient hospitals in the United States are non-profits, and so are all orchestra and opera theatres in the United Kingdom and Japan (Bilodeau and Steinberg, 2006). In the OECD countries, on average, 7.5 per cent of economically active population is employed in the non-profit sector, and for some countries (Belgium, Netherlands, Canada, U.K., Ireland) this share exceeds 10 per cent (Salamon, 2010). Non-profits provide public goods in such diverse sectors as education, health, environment, social protection, arts and culture, and human rights. The key issue is, therefore, whether non-profit provision (and ownership of key assets used in provision) of public goods is socially desirable. The seminal paper by Besley and Ghatak (2001) provides the first answer to this question: they argue that the ownership of such assets should be given to the party (i.e. to the government or to the non-profit organization) that has the highest valuation of the public good, regardless whose investment increases more the value of the public-good project.

However, this general normative analysis does not provide guidance about *how* the transfer of ownership of public goods to non-profits (in case these have the highest valuation) should be organized. This is a fundamental policy question, given that governments dispose of a rich set of tools that can affect the incentives for the non-profit ownership of assets used for public good provision. These tools include, among others, subsidies for purchase of assets from private holders, direct grants to non-profits, tax exemptions to private sellers, etc. Designing an effective policy requires, first of all, understanding - theoretically and empirically - the effects of such policies on the behaviour of non-profits and the outcomes on the asset markets. Economists' current knowledge in this area is extremely limited, in particular, at the level of a market. Insights from standard microeconomic analysis of markets provide only limited answers, given that nonprofits possibly react to financial incentives in ways which are systematically different from those of their for-profit counterparts.

A crucial difference between for-profit and non-profit organizations is that non-profits are legally barred from redistributing profits. This "non-distribution constraint" first formally introduced by Hansmann (1980), is at the heart of some of the main particularities of the non-profit sector. Non-profits are predominant in the provision of goods characterized by a high non-contractible quality content, such as health, the arts, or biodiversity (Kuan, 2001; Castaneda et al., 2008). Asymmetries of information make most for-profits unreliable in the delivery of these goods characterized by unmeasurable quality. Thus, users prefer to rely on organizations whose members are motivated by something else than profit maximization. Nonprofits have instead "missions", which usually differ between organizations: each has a particular appraisal of the quality form and content that should be embedded in the public good they provide. Given this heterogeneity, missions can more or less accurately mirror the preferences of donors. Nonprofits can improve the matching of their mission with the donor's preferences by either adapting their mission, or by persuading donors of the soundness of it (Rose-Ackerman, 1982; Aldashev and Verdier, 2010).

In this paper, we evaluate the short-run and long-run effects of a government subsidy to non-profit ownership of assets used in public-good projects. We first develop a dynamic model of a market for assets populated by competing non-profits. The market is decentralized and finding each new potential asset requires some search (prospecting) efforts by the nonprofit. The nonprofit can persuade, at a cost, sellers into contributing to the mission by either donating or accepting a lower payment for the asset they sell. A good performance by a nonprofit at any given period attracts volunteer labour in subsequent periods. This creates a virtuous circle because new volunteers engage in new prospecting efforts, which expand supply. We show that the introduction of a subsidy starts such a virtuous circle. Initially, the subsidy increases units exchanged and prices paid. The increase in purchased quantities immediately after the shock attracts more volunteer labour, which in turn prospects to increase supply. At the steady state, a permanent subsidy permanently increases purchased quantities, while prices fall back to their pre-subsidy levels.

Next, we test these predictions using a unique dataset that we have constructed from notarial land-purchasing acts in the Walloon region of Belgium. This dataset includes all the land purchases by environmental conservation non-profits in Walloon region between 1950 and 1994. Importantly, our data allows us to study the effect of the policy reform undertaken in 1986, when the regional government introduced an ad valorem subsidy to land purchase by non-profits. The non-contractible quality cannot – by definition – be measured; however, other main predictions of the model are testable. We find that exchanged quantities increase substantially, while the effect on the asset price varies over time, in the way predicted by our model: the subsidy creates a sharp price increase in the short-run, followed by a gradual decline of the land prices. We argue that this occurs because the subsidy makes tradable goods (land) relatively cheaper than non-tradable assets (time), inducing non-profits to reallocate their time/human resources from quality-improving efforts into quantity-expanding activities, namely fundraising and prospecting activities. Because the reallocation of internal resources takes some time, the subsidy initially creates a demand shock by increasing the purchasing power of the nonprofits, and over time prices gradually decrease due to the reallocation of non-tradable resources into searching and negotiating activities. This non-linear trend in prices is empirically identified thanks to the fact that the introduction of the subsidy was unexpected by market participants, and because comparable land unaffected by the reform did not exhibit any similar pattern regarding their prices. In addition, while we cannot directly observe quality, the data shows that nonprofits for which quantity-based objectives are emphasized in their mission statements capture a significantly more important share of the market, compared to nonprofits emphasizing quality-based objectives in their mission statements.

Our paper also makes a methodological contribution to the empirical analysis of markets for assets with a public-good component. A broad range of markets in which non-profits represent the buyer side fall into this category: the markets for works of art, labour markets for jobs in the non-profit sector, etc. In such markets, the motivation of actors on the supply side often consists of a mix of profit-oriented and altruistic elements, and thus such actors are often willing to sell the assets at a reduced or symbolic price or donate them. Data from such markets thus usually contain numerous observations that are considered as outliers. We show that by the use of an appropriate estimator robust to outliers (the MS-estimator, developed by Maronna and Yohai, 2000), one can estimate the trends in market outcomes much more accurately.

The structure of the rest of the paper is as follows. Section 2 presents our theoretical model of a market for assets and derives testable predictions. Section 3 describes the context from which our data is collected, provides a short history of natural reserves in the Walloon region and describes the dataset. Section 4 presents our identification strategy, the descriptive statistics and the results of the regression analysis. Section 5 discusses the interpretation of our empirical results and the methodological contribution. Section 6 highlights the broader implications of our findings and concludes.

## 4.2 Model

During each period $t$, there is a unit size continuum of size $k$ potential sellers, each endowed with one unit of an asset required for the production of a public good. A set of $i \in N$ non-profit Organizations (NPOs) are potentially interested in purchasing such assets. The market is decentralized, and NPOs have to exert a time-consuming effort $n_t^i$ to find, bargain and match with potential sellers. For simplicity, suppose that that $k$ is sufficiently large, or prospecting sufficiently inefficient, for the probability of a seller being discovered by more than one NPO simultaneously is negligible. Define $n_t^i$ as the *prospecting effort* exerted by each NPO, expressed in units of time. This effort has two effects: first, it allows the NPO to discover $n_t^i$ potential sellers, and secondly, it persuades discovered sellers to accept a lower price for their asset. This second effect arises through bargaining and persuasion. Conditional on being discovered, a seller trades if the price $p_t^{ik}$ proposed by the NPO is above her reservation price $\gamma^k$.

Suppose that $\gamma^k$ follows a uniform distribution defined as follows:

$$\gamma^k \backsim U\left[0, \frac{1}{n_t^i}.\right]$$

While NPOs do not know the exact reservation price of the sellers, prospecting efforts narrow its distribution. Conditionally on discovering a seller, trade occurs with probability $n_t^i p_t^{ik}$. Given that the NPO discovers $n_t^i$ potential sellers, the supply that $i$ faces is

$$q_t^i = \int_k {n_t^i}^2 p_t^{ik} dk = {n_t^i}^2 p_t^i$$

in which $q_t^i$ are the units of asset supplied at $t$, and $p_t^i$ denotes the average price paid by NPO $i$. Note that the square exponent of the prospecting efforts captures the double dividend of discovering sellers, and reducing expected reservation prices.

The inverse supply function writes

$$p_t^i = \frac{q_t^i}{{n_t^i}^2}. \tag{4.1}$$

The mission of each non-profit is the provision of a public good which has a quantity and a quality dimension. The public good uses the aforementioned $q_i^t$ assets as an input. Let us denote the quantity and the quality of the public good provided by non-profit $i$ with $q_i$ and $x_i$. Each non-profit manager has $v_t^i$ units of volunteer labour time that she allocates between improving the quality of the public good $(x_t^i)$, conducting fundraising activities $(f_t^i)$, and searching/prospecting for the assets necessary to the production of the public good $(n_t^i)$. Given the legal non-profit status, the organizations cannot distribute earnings amongst its members. The optimization problem of non-profit $i$ at period $t$ is:

$$\begin{aligned}
\max_{\{q_t^i, x_t^i, n_t^i, f_t^i\}} \quad & q_t^i {x_t^i}^{\omega^i} && \text{[Objective function]} \\
\text{s.t} \quad & v_t^i \geq x_t^i + f_t^i + n_t^i && \text{[Time constraint]} \\
& (1-\sigma) p_t^i q_t^i \leq \mu f_t^i && \text{[Non-distribution constraint]}
\end{aligned}$$

with $p_t^i = q_t^i / {n_t^i}^2$. Each NPO pursues the double objective of increasing the quantity and quality of the public good it produces, weighted by $\omega^i$ in the Cobb-Douglas objective function. $\omega^i$ increases with the intrinsic preference for the quality dimension. Notice that we implicitly assume that time devoted to improve quality during period $t$ applies only to assets purchased during this period; stocks of assets purchased in previous periods have already benefited from quality improvements and remain unchanged in subsequent periods. A simple way of justifying this assumption is by stating that available volunteer hours $v_t^i$ are net of time resources sunk in the management of previously purchased lands. The Cobb-Douglas objective function prevents that changes in the price of assets directly modify the allocation of volunteer time: this choice is made to prevent our results from being explained by simple substitution effects. The first inequality in the optimization programme displays the time resource constraint of the organization in terms of volunteer hours available at period $t$. The non-distribution constraint states that all the funds available to the non-profit have to equal its expenditures for public good provision (i.e. the organization cannot distribute profits to its owners/members). The only expenditure item is assets purchased. Government provides the ad valorem subsidy $\sigma \in [0, 1]$ for asset purchase over the paid price $p_t^i$. On the revenue side, the available funds are obtained through donations (collected thanks to fundraising activities with the simple linear technology $\mu f_t^i$).

### 4.2.1 Static Equilibrium

The Lagrangian associated to the problem of the NPO is :

$$\mathcal{L}(q_t^i, x_t^i, n_t^i, f_t^i, \lambda_t^i, \nu_t^i) = q_t^i x_t^{i\omega^i} - \lambda_t^i \left[ (1-\sigma) \left( \frac{q_t^i}{n_t^i} \right)^2 - \mu f_t^i \right] + \nu_t^i (v_t^i - x_t^i - f_t^i - n_t^i)$$

in which $\lambda_t^i$ and $\nu_t^i$ are the Lagrange multipliers. Solving this problem characterizes the static equilibrium (details are provided in the appendix). In terms of the allocation of available volunteer time we obtain

$$\begin{aligned} x_t^{i*} &= \frac{2\omega^i}{3+2\omega^i} v_t^i \quad \text{[Time devoted to improving quality]} \\ n_t^{i*} &= \frac{2}{3+2\omega^i} v_t^i \quad \text{[Time devoted to prospecting for assets]} \\ f_t^{i*} &= \frac{1}{3+2\omega^i} v_t^i \quad \text{[Time devoted to fundraising]} \end{aligned}$$

The specification of the objective function makes the allocation of time invariant in changes of the relative price of the assets. As one could expect, when the NPO weights more quality relative to quantity (when $\omega^i$ increases), time devoted to improve quality increases, to the detriment of prospecting and fundraising activities. More available volunteer hours increase the time devoted to all three activities by a fixed proportion.

Concerning quantities purchased, the optimization program obtains:

$$q_t^{i*} = 2\left(\frac{v_t^i}{3+2\omega^i}\right)^{3/2}\left(\frac{\mu}{1-\sigma}\right)^{1/2} \tag{4.2}$$

Improvements in the fundraising technology ($\mu$), and increases in the subsidy ($\sigma$) relax the non-distribution constraint of the NPO, allowing it to purchase more assets. More volunteer hours allow the NPO to devote more time to prospecting activities, finding more potential sellers and persuading them of selling more assets. As noted above, an increased focus on the quality dimension reduces time devoted to prospecting, driving down quantities purchased.

Finally, the equilibrium price paid by $i$ is:

$$p_t^{i*} = \sqrt{\frac{3+2\omega^i}{v_t^i}\cdot\frac{\mu}{1-\sigma}} \tag{4.3}$$

As fundraising technology improves, prices increase because the NPO has more disposable income, shifting the demand curve upwards. An increased focus on quality increases prices as well, because less time is devoted to prospecting, which results in worse deals for the NPO. On the contrary, more available volunteer time increases prospecting. Finally, an increase in the subsidy shifts the demand curve up, increasing prices, as in any typical market. Next, we explore how this equilibrium changes dynamically.

### 4.2.2 Dynamics

Assume that the number of volunteers willing to adhere to a certain NPO depends on its performance in the previous period. Namely, volunteers adhere to the organization if it has performed well in the quantity and in the quality dimension. Because quality is by assumption non-observable, volunteers infer the quality improvements by observing how much time has been devoted to (observable) fund raising and prospection. The more time the NPO devotes to these activities, the less volunteers are willing to adhere, as they feel that it does not invest sufficient resources in the desirable output. In other words, the NPO appears to less driven by the mission, and more by a budget-maximizing strategy. Assume that

$$v_{t+1}^{i} = \frac{q_t^i}{f_t^i + n_t^i}. \tag{4.4}$$

Substituting by the static equilibria values of $q_t^i$ ,$f_t^i$, and $n_t^i$ at any period $t$, this rewrites as a law of motion of volunteer time:

$$v_{t+1}^{i} = \frac{2}{3}\left[\frac{\mu}{1-\sigma}\frac{v_t^i}{3+2\omega^i}\right]^{\frac{1}{2}}.$$

This particular law of motion is a calibration adapted to emulate the results obtained in the empirical section of this paper. It ensures a closed-form solution and a convergent time series; other laws of motion, if convergent, would produce qualitatively similar results to those obtained here. The 1/2 exponent on $v_t^i$ guarantees that this series is convergent.

From any initial arbitrary volunteer time $v_0^i$, the law of motion obtains

$$v_t^i = \left[\frac{2}{3}\left[\frac{1}{3+2\omega^i}\cdot\frac{\mu}{1-\sigma}\right]^{\frac{1}{2}}\right]^{2-2^{1-t}} {v_0^i}^{2^{-t}} \tag{4.5}$$

which is the value of $v_t^i$ at any period $t$ depending in the initial stock of volunteer time. The Appendix proves this statement. Note that there is some path dependence, as the initial stock of volunteer hours determines the subsequent trajectory. As $t$ increases, volunteer time converges to its steady state value

$$v_{SS}^i = \frac{4}{9}\left[\frac{1}{3+2\omega^i}\cdot\frac{\mu}{1-\sigma}\right]. \tag{4.6}$$

Remark that the steady state is independent from the initial volunteer labour time. Relaxing the non-distribution constraint increases quantities purchased, attracting more volunteers in the long run. Finally, quality-oriented NPOs will attract less volunteers in the long run. The quadratic supply function indicates that the returns of prospecting are surpass those of investing in quality; each unit of labour devoted to prospecting increases purchases more than it would have improved quality, therefore quantity-oriented NPOs will attract relatively more volunteers.

Plugging $v_{SS}^i$ in equations (4.2) and (4.3) one obtains the steady state quantities and prices:

$$q_{SS}^i = \frac{16}{27}\left(\frac{1}{3+2\omega^i}\right)^3\left(\frac{\mu}{1-\sigma}\right)^2$$

$$p_{SS}^i = \frac{3}{2}(3+2\omega^i)$$

**Proposition 4.1** (Steady state prices and quantities)**.** *Under the law of motion of volunteer labour defined in (4.4), the steady state for each NPO in this decentralized market is such that:*

1. *if fundraising technology improves or if the government introduces subsidies, then the amount of assets purchased increases at the steady state;*
2. *if the NPO weights more quality than quantity, then at the steady state prices paid are higher and quantities purchased are smaller;*
3. *the subsidy has no effect on the steady state price.*

It is immediate that:

$$\frac{d^2 q_{SS}^i}{d\sigma d\omega^i} < 0$$

**Corollary 4.1** (Effect of the subsidy across NPOs)**.** *NPOs more concerned with the quality dimension will buy proportionately less assets when the subsidy is introduced. It follows that the subsidy will decrease the market share of those more concerned with the quality dimension.*

Let us study now the effect of the introduction of the subsidy in the short run by examining the transition from the pre-subsidy steady state to the steady state in which the government finances the permanent subsidy. Denote $t = 0$ the period at which the subsidy is introduced. The moment at which the unexpected subsidy is introduced, the number of volunteers remains at the pre-subsidy steady state until new recruitments occur. By (4.6),

$$v_{SS}^{i,ea} = \frac{4}{9}\left[\frac{\mu}{3+2\omega^i}\right]$$

in which $v_{SS}^{i,ea}$ denotes the *ex-ante* steady state. The moment the subsidy is introduced, using (4.3) and (4.2) we how that prices and quantities jump to:

$$p^i_{t=0} = \frac{1}{\sqrt{1-\sigma}}\frac{3}{2}(3+2\omega^i)$$

$$q^i_{t=0} = \frac{1}{\sqrt{1-\sigma}}\frac{16}{27}\left(\frac{1}{3+2\omega^i}\right)^3\mu^2$$

Immediately after the introduction of the subsidy, prices and quantities are multiplied by scalar $(\sqrt{1-\sigma})^{-1}$ larger than one. By substituting the *ex-ante* steady state volunteer time as an initial condition in (4.5), the number of volunteers at each $t$ after the shock is

$$v^i_t = \left(\frac{1}{1-\sigma}\right)^{1-2^{-t}}\frac{4}{9}\left[\frac{\mu}{3+2\omega^i}.\right] \tag{4.7}$$

From it, we obtain the motion of quantities and prices following the introduction of the subsidy:

$$q^{i*}_t = \frac{16}{27}\left(\frac{1}{3+2\omega^i}\right)^3\mu^2\left(\frac{1}{1-\sigma}\right)^{2-3\cdot 2^{-t-1}}$$

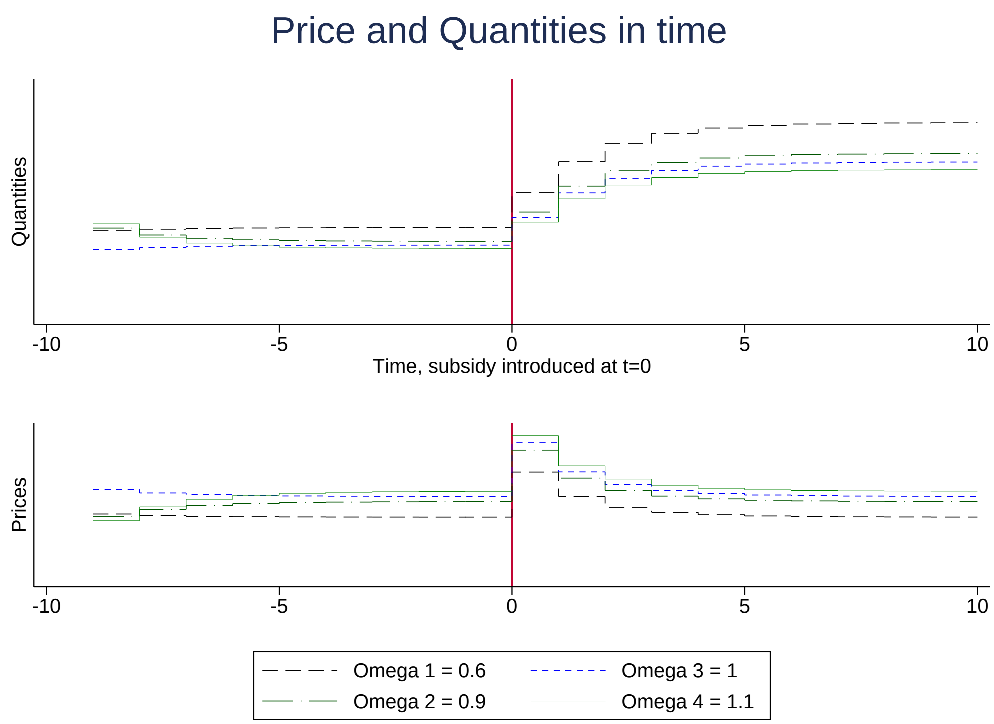
$$p^{i*}_t = \frac{3}{2}(3+2\omega^i)\left(\frac{1}{1-\sigma}\right)^{2^{-t-1}}$$

**Proposition 4.2** (Motion of prices and quantities)**.** *Under the law of motion of volunteer labour defined in (4.4), the introduction of an unexpected permanent subsidy is such that:*

1. *immediately after the introduction of the subsidy, there is a hike of demand, which increases prices,*
2. *the price of the assets progressively declines while purchases progressively increase*
3. *at the new steady state, the price converges to the pre-subsidy situation, while the increase in purchases is permanent.*

We test this proposition in the empirical section of the paper. Figure 4.1 plots quantities and prices for four NPOs, which vary in their degree of concern for the quality of the public good. We fix $\mu = 1$ and $\sigma = 0.5$ which corresponds to a 50% ad-valorem subsidy. Initial available voluntary hours are arbitrarily fixed. Before the

Figure 4.1 – Motion of Prices and Quantities after the introduction of the Subsidy.




permanent subsidy unexpectedly introduced at $t = 0$, prices and quantities converge to the *ex-ante* steady state. At the moment of the shock, both prices and quantities hike, then prices progressively return to their pre-subsidy levels, while quantities continue rising until reaching a new, higher, steady state.

## 4.3 Institutional context and data

### 4.3.1 Natural reserves worldwide and in the Walloon Region

The first American national park, the Yellowstone, was established by the U.S. Congress already in 1872. In Europe, the formal institutions for the conservation of nature started somewhat later and were much more grassroot-driven. The United Kingdom and France saw the birth of private conservation charities in 1895 and 1901, respectively. These societies had the mission of protecting countryside landscapes, scenic beauty, and major natural sites (Lansley, 1996; Lepart and Marty, 2006). In the UK, the National Trust almost immediately started to buy land plots and buildings from private owners. It created several natural reserves and progressively became the main private actor of environmental policy in the UK. Thanks to its two million members, the National Trust has relieved the UK government from a substantial part of its tasks in the environmental conservation domain; in exchange, the government granted the charity with considerable fiscal advantages. In France, the *"Société pour la Protection des Paysages et de l'Ésthétique de la France"*, the oldest French environmental non-profit association chose instead a strategy focused on lobbying the government on various environmental policies. France passed its first environmental-protection laws in the beginning of the 19th century, while its first national park was established in 1913.

Currently, throughout the world, private foundations aimed at creation and protection of natural reserves play an important role both in public-good provision and advocacy. The prominent example is The Nature Conservancy, a U.S.-based global-operations environmental charity. With more than one million members, Nature Conservancy manages over 8000 kilometers of rivers and 50 million hectares of land (a surface exceeding that of California) in more than thirty countries (www.nature.org).

Belgium (and especially the Walloon Region, the Southern half of the country) exhibits a system of environmental conservation that combines certain aspects of the French mostly public sector-oriented approach with some characteristics of the British charity-based approach. In 1943, *Ardenne et Gaume*, an environmental non-profit, created the first natural park in the Walloon Region. In subsequent thirty years, the environmental non-profits kept playing the major role of environmental public good providers, by either contracting long-term leases or purchasing and managing new plots of land. Initially, the budgets of non-profit consisted mainly of private contributions and donations, complemented by small-scale commercial activities.

The national government showed interest in the natural park creation and management around 1957 and made its first acquisition of land in 1972. Political decentralization of Belgium implied that the conservation of nature fell under regional jurisdiction in 1980, and the government of the Walloon Region created a new strategy, which included a set of policies towards environmental non-profits. Most importantly, in 1986 the regional government passed a reform (with retroactive effect to January 1, 1985) introducing large subsidies to environmental non-profits. This reform essentially consisted of two sets of subsidies. The first (and by far the most important) is a subsidy for land acquisition, consisting of paying (reimbursing) 50 per cent of the price of land plots that a legally registered non-profit purchased from a private owner (with the scope of creating a natural reserve) on any date after Jan. 1, 1985. The second is a subsidy for management expenses of natural reserves, which consists of covering 50 per cent of effective ordinary management expenses (or an annual lump-sum of around 100 Euros per hectar of certified natural-reserve surface) and of fully covering the extraordinary (emergency) expenses. To qualify for these subsidies, the land plot acquired by a non-profit should obtain the status of "*Réserve Naturelle Agrée*" (RNA hereafter) from the Department of Nature and Forests of the Walloon regional government, following the decision of a council of experts. This council (composed of scientists, non-profit representatives, and public servants) is the only administrative structure that has the right to decide on the RNA status. Its main task that of verifying whether the proposed land area has a sufficiently high environmental value. This council also plays a similar role in the creation of the public counterpart of RNAs, called "*Réserves Naturelles Domaniales*" (RNDs), that are publicly owned and managed.

Given the substantial expertise of the council members, virtually all the existing natural reserves are created on the land areas with a relatively high environmental potential. Such land typically has few alternative production uses (such as intensive agriculture) but, if properly managed, can yield considerable positive externalities (protection of natural habitats and endangered species, environmental tourism, etc.). Thus, the main actors in the Walloon region on the buyer side of the market for this type of land are the legally recognized environmental non-profits (there are ten such organizations in the region) and, to some extent, the regional government. The seller side consists of a multitude of small landowners (many of whom are heirs of individuals that bought these land plots in the past mostly for extensive pastoralism or to diversify their wealth portfolios).

### 4.3.2 Data

The data that we collected comes from the archives of the branch of the Walloon regional administration that is in charge of the conservation of nature [2]. This branch is in charge of administering payments of subsidies to environmental non-profits both for land acquisition and for the management of the natural reserves. We construct our data using the certified copies of notary deeds of land acquisitions by non-profits from private owners, that the legally registered environmental non-profits have to provided to the DGO3 in case they receive any subsidy. Importantly, even though the policy was introduced in 1986, subsidies for ordinary management expenses are paid for natural reserves regardless of their date of creation. Provided that the land plot has a sufficiently high environmental value, conditions to fulfil in order to qualify for the ordinary-management subsidy are quite loose. This implies that for the year range 1943 to 2010, we have data on virtually all the land transactions related to creation of private natural reserves. In this paper, we restrict our analysis to the period between January 1950 and March 1994 for two main reasons: (1) there is no price deflator available for the observations before 1950, and (2) starting April 1994, the European Union started to provide additional subsidies for environmental non-profit land purchases through the program (with somewhat different eligibility conditions), which we plan to investigate in future work.

From each notary deed, we extracted (and quantified, wherever needed) information about the transaction, i.e. the date and the price at which land was purchased, identities of both parties, and precise information about land plots (geographic characteristics, cadastral number, size of the plot, and the exact location). Importantly, given that our sources are the notary deeds, we can disregard the problems related to misreporting, which usually have to be addressed in survey-based data.

## 4.4 Empirical Analysis

### 4.4.1 Identification strategy

Our identification strategy relies on the discrete change in policy towards non-profits introduced in 1986 by the Walloon regional government, as described above.

2. Direction Générale Opérationelle 3 (DGO3)

This policy change deeply modified the incentives faced by non-profits. We want to analyze the behavioral response of non-profits to this policy change, both in the short- and the long run, as compared to the behavior and outcomes before the policy reform.

We argue that this identification strategy is valid because the policy reform was unanticipated and not simultaneous with any other major change in environmental policies. The reform was carried out by a coalition government consisting of Christian-Democrats and Liberals, shortly after this government was formed. Given that the Walloon region is traditionally a stronghold of the Socialist Party, this particular government is (so far) the only regional government in the history of the Walloon region where Socialists were not in power, and for the first time, the minister of environment was a Liberal and not a Socialist. Given the Belgian political context, prior to the elections that led to formation of this government, it was thus extremely difficult to foresee the exact composition of this government and the identity of ministers' cabinet members. Moreover, the reform was not widely discussed, neither at the regional parliament, nor in the media, essentially because in that particular period, tensions between the French-speaking and the Flemish-speaking communities in Belgium occupied most of the public debates, and the environmental conservation was definitely not considered a key issue [3].

The timing of elections and of the implementation of reform also limited potential anticipation effects. The regional government was in place from December 1985 onwards, following the regional election in October 1985. The reform was then passed, in a relatively short period of time. Transactions on the land market, instead, require substantial amount of time to be concluded [4]. Thus, this timing leaves little space for the reform to have retroactive effects on transaction prices before July 1986. For robustness, we provide additional evidence below that our findings are not driven by purchases between 1985 and July 1986. If anything, our estimates provide a lower bound, if some of the land transactions finalized after July 1986 had not yet been influenced by the reform.

Our identification relies on the policy break and on comparing the land plots

3. Reading through the major regional newspapers in the period 1985-87, we could not find any article discussing this reform.

4. Typically, once the buyer and the seller agree on the transaction details, they sign a provisional sale agreement in front of a notary; a procedural delay of two to four months usually follows, before the final bill of sale is signed in the notary's office.

with similar characteristics transacted before and after the reform. However, one key concern is that other (unobservable) changes in the environment of the market for land might have occurred around the same time. This would jeopardize our identification. To allay this concern, we collected the data on the aggregate market prices for comparable types of land (woodland and farm land/pastures). We use these series to show that there are no similar changes in the prices for these types of land (that do not qualify for the subsidy), in the several years before and after the policy reform.

### 4.4.2 Descriptive statistics

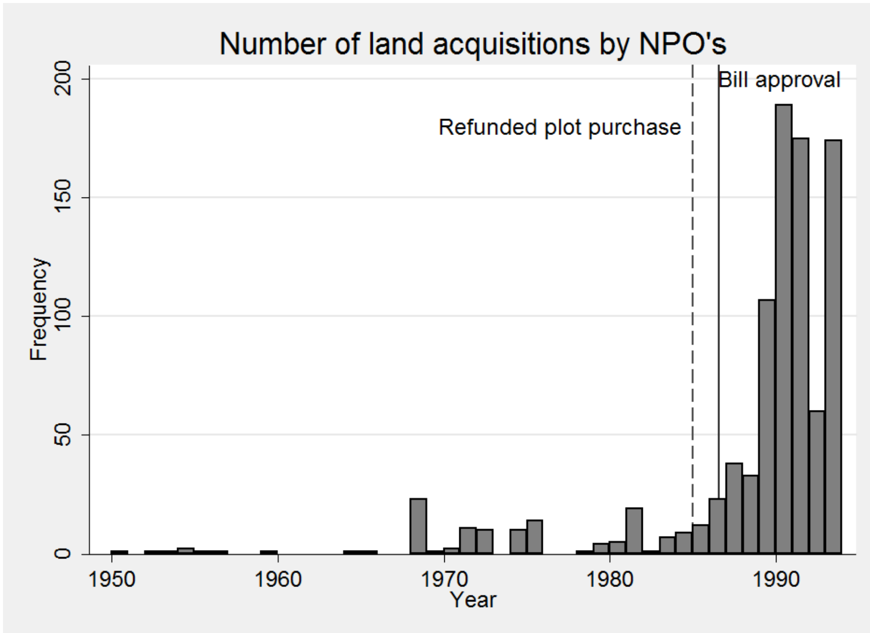
The dataset that we use for this paper consists of 938 land plots acquired by environmental non-profits between 1950 and 1994. This represents virtually the universe of such land purchases within this time period [5]. Transactions at the beginning of this period are few, given that systematic land purchase by non-profits started in the 1970s, followed by a boom in both the quantity and the size of transactions in the 1990s, as can be seen in Figure 4.2. 148 plots were purchased before the reform and 790 were bought after it. Twenty-one plots were purchased between January 1, 1985 (the date of retroactive effect of the reform) and the official announcement of the reform.

The land surface purchased increased substantially: it rose from 134 hectares before the reform to 728 hectares after it. The number of environmental non-profits buying land increased as well: three non-profits were buying land before 1986, whereas after the reform this number doubled. However, the market structure became much more concentrated. Before the reform, two non-profits had relatively large market shares (71 and 27 per cent, respectively), leaving a residual market share to the third actor. After the introduction of subsidies, the largest buyer increased its market share even further (up to 93 per cent of the market), becoming a de facto monopolist (as depicted in Figure 4.3).

Table 4.1 presents descriptive statistics of our main variables before and after the reform of July 1986. In addition, we also look at a sub-sample of observations which are potentially strongly affected by the reform and are less affected by potential unobservable variables. This restriction allows us to exclude the surge in the number

5. We lose 11 observations because of missing information on the transaction price.

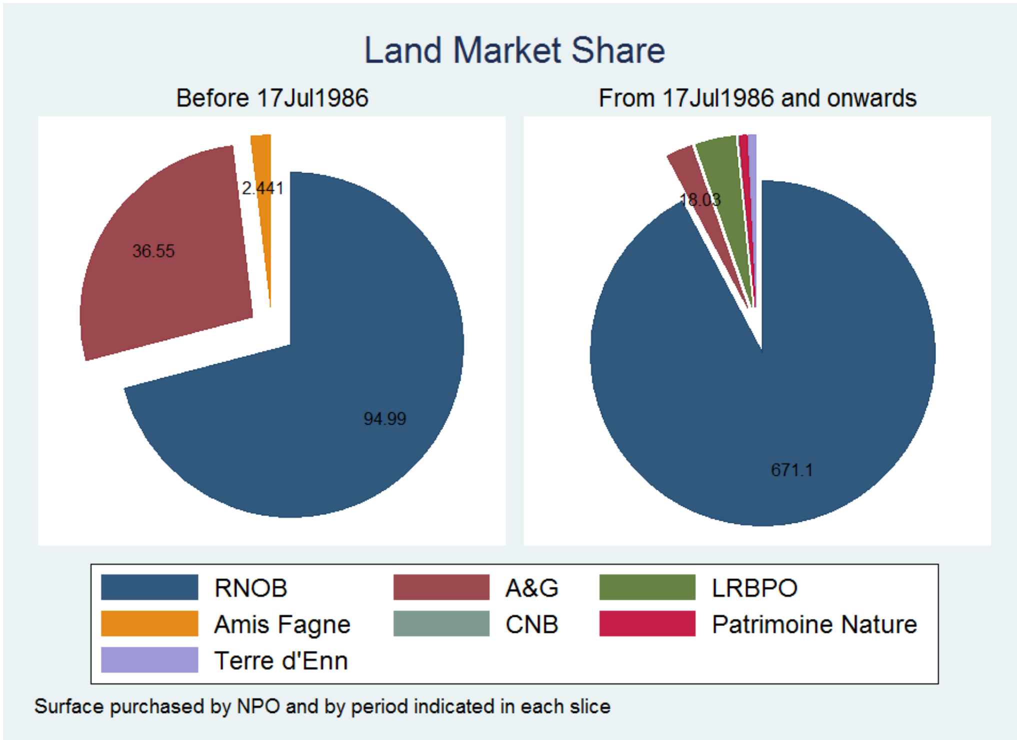
Figure 4.2 – Number of land transactions with non-profits as buyers




of plots purchased in the early 1990s, where other time-varying factors might be driving this dynamics. In this sub-sample, we thus focus on 75 observations after the reform and compare them to 75 observations just before it (we also compare the post-reform observations to 75 acquisitions before January, 1 1985, the earliest purchase date to qualify for the subsidy).

In all comparisons, prices after the reform are higher than those before the reform. The difference is statistically significant only when we restrict the comparison to observations shortly before and shortly after the reform; however, notice that the variance in prices also increases considerably. Average plot size remains relatively stable (slightly below one hectare). Around half of the plots were owned by multiple sellers (these typically are multiple heirs of the landowning farmer). This share falls to less than 40 per cent after the reform. In addition, there are two large changes in the portfolio of plots purchased by the non-profits. First, there is a change in land occupation pattern of purchased plots. After the reform, non-profits seem to buy more woodlands, wetlands and pasture lands, and fewer wastelands. However, the change in the quality of land is small when we restrict our comparison to the 150-

Figure 4.3 – Land market share, by non-profit, before and after the reform




observation window (dropping the observations in the "grey" area between early 1985 and July 1986). The differences in land quality are not statistically significant in this restricted window (because point estimates are smaller and not because difference-in-means tests are less accurate in smaller sample). Finally, as shown in Figure 4.4, non-profits increase the geographic spread of their purchasing activity after the reform. They remain highly active at their core area in the Eastern part of the Walloon region, but start to buy plots in other provinces where land prices are, on average, higher. This might indicate that after the reform non-profits increase their search and prospecting efforts.

Figure 4.4 – Location of acquisitions in the Walloon region before and after the reform

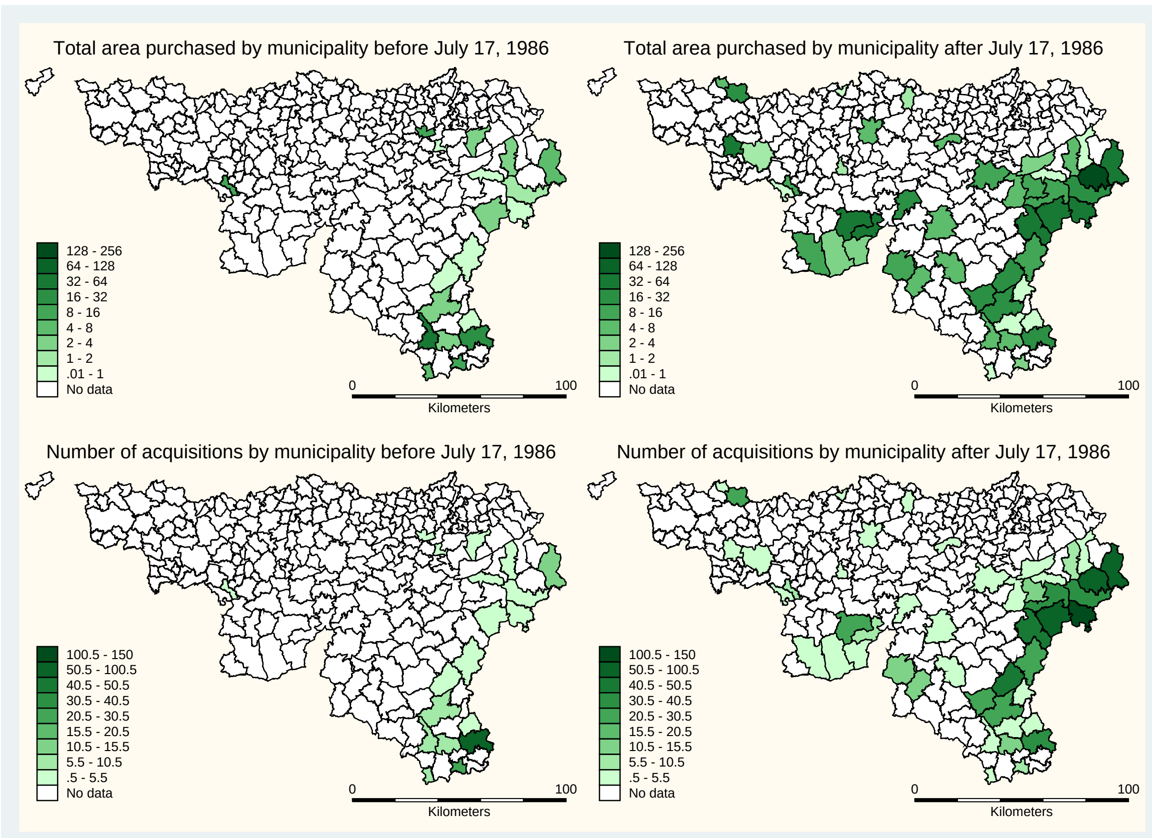


Table 4.1 – Descriptive statistics

| | Before 17Jul86 | | After 17Jul86 | Before 17Jul86 | | Before 01Jan85 | | After 17Jul86 |
|---|---|---|---|---|---|---|---|---|
| | mean/sd | | mean/sd | mean/sd | | mean/sd | | mean/sd |
| Price | 2814.95 | | 3470.30 | 2654.69 | | 2144.45 | ** | 4188.67 |
| | (9342.50) | | (13007.01) | (4920.10) | | (4581.21) | | (7394.07) |
| Surface | 0.91 | | 0.92 | 0.90 | | 0.80 | | 0.99 |
| | (2.72) | | (3.54) | (1.79) | | (1.75) | | (1.39) |
| Price per hectare | 3642.00 | | 5111.39 | 4062.82 | | 3802.83 | | 4859.73 |
| | (2923.65) | | (19306.64) | (3763.14) | | (3559.86) | | (7775.41) |
| Number of co-owners | 1.90 | | 1.78 | 1.91 | *** | 2.03 | *** | 1.44 |
| | (1.50) | | (1.46) | (1.43) | | (1.61) | | (0.87) |
| =1 if co-owned | 0.47 | | 0.38 | 0.49 | *** | 0.48 | ** | 0.28 |
| | (0.50) | ** | (0.49) | (0.50) | | (0.50) | | (0.45) |
| =1 if waste land | 0.30 | | 0.06 | 0.17 | | 0.21 | | 0.16 |
| | (0.46) | *** | (0.24) | (0.38) | | (0.41) | | (0.37) |
| =1 if woodland | 0.03 | | 0.16 | 0.07 | | 0.01 | *** | 0.12 |
| | (0.18) | *** | (0.37) | (0.25) | | (0.12) | | (0.33) |
| =1 if wetland | 0.01 | | 0.05 | 0.03 | | 0.03 | | 0.00 |
| | (0.12) | ** | (0.22) | (0.16) | | (0.16) | | (0.00) |
| =1 if pasture land | 0.55 | | 0.67 | 0.67 | | 0.64 | | 0.56 |
| | (0.50) | *** | (0.47) | (0.47) | | (0.48) | | (0.50) |
| =1 if pond | 0.00 | | 0.02 | 0.00 | | 0.00 | ** | 0.05 |
| | (0.00) | | (0.13) | (0.00) | * | (0.00) | | (0.23) |
| =1 if cult. land | 0.11 | | 0.12 | 0.09 | | 0.09 | | 0.13 |
| | (0.32) | | (0.33) | (0.29) | | (0.29) | | (0.34) |
| =1 if out of core area | 0.01 | | 0.15 | 0.03 | | 0.01 | | 0.12 |
| | (0.12) | *** | (0.36) | (0.16) | ** | (0.12) | *** | (0.33) |
| Observations | 148 | vs. after | 790 | 75 | vs. after | 75 | vs. after | 75 |

*, **, *** denote significant differences between values before and after, respectively at 10%, 5% and 1%

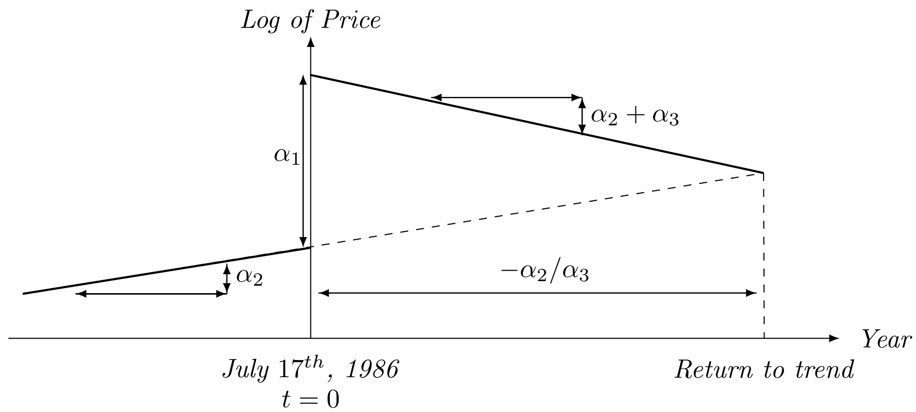



Figure 4.5 – Interpretation of regression coefficients

### 4.4.3 Regression analysis

As explained above, our econometric analysis relies on the discontinuity around the policy reform date. We thus estimate the relationship:

$$Lnprice_i = \alpha_0 + \alpha_1 Policy_i + \alpha_2 Year_i + \alpha_3 Policy_i * Year_i + \mathbf{X}_i\beta + \varepsilon_i. \tag{4.8}$$

Here, $Lnprice_i$ is log of the (deflated) purchase price of plot $i$, $Policy_i$ is an indicator variable that takes value 1 if the plot was purchased under the subsidy regime, and zero otherwise, $Year_i$ denotes the year of transaction (amending for temporal auto-correlation), $\mathbf{X}_i$ is a vector of control variables (size of the plot, number of sellers, geographic characteristics, identity of the buyer, etc.), and $\varepsilon$ an idiosyncratic component. Figure 4.5 presents the interpretation of the main coefficients. $\alpha_1$ denotes the average short-term change in prices of land plots driven by the policy change (i.e. with the year of the policy change is referenced as $Year = 0$). Since our dependent variable is expressed in logs and $Policy_i$ is a binary variable, the exact predicted average change between the prices of subsidized and non-subsidized land purchases equals $e^{\alpha_1} - 1$. $\alpha_2$ controls for the overall time trend in prices, whereas $\alpha_3$ allows to capture the difference in time trends between the period before the reform and the one after the reform. In a linear specification, the time necessary to revert to the pre-reform trend after the policy reform is given by the ratio between $\alpha_1$ and $\alpha_3$, provided that these two coefficients have opposite signs. Table 4.2 reports the results of estimating of equation (4.8) by ordinary least squares. Point estimates of

$\alpha_1$ are systematically positive, relatively large but very imprecise (standard errors are clustered at municipality level); therefore, the coefficient is never significantly different from zero in any of our specifications. However, it is worth noting that estimates of both $\alpha_1$ and $\alpha_3$ are relatively stable when we add controls for the number of sellers, land quality (geographic characteristics), and whether the plot is located in a province where there were no purchases before 1986. Specification (5) adds controls for the identity of the buyer (i.e. non-profit fixed effects). Taking into account that only two non-profits engaged in land purchase transactions both before and after 1986, these controls purge our estimated coefficients from a potentially different market behaviour of new buyers. The estimated coefficient $\alpha_1$ increases substantially, which suggests that new entrants buy, on average, at lower prices than the two incumbents. Observing the two main coefficients of interest jointly, we find some evidence in favour of an increase in prices after the introduction of subsidies; however, this increase looks temporary as suggested by a negative sign of $\alpha_3$ (the coefficient of the interaction term between the time trend and the policy dummy). Qualitatively identical results obtains when prices and land area are evaluated in levels (not reported).

The methodology used for these estimations is unsatisfactory, as clearly indicated by the coefficients of the plot area. In general, land market prices are almost perfectly proportional to the plot size; our discussions with several notaries involved in such transactions indicate that in most transactions, the purchase price is roughly calculated as the price per-hectare multiplied by the plot surface (after taking into account the land quality). Therefore, we should observe that a one percent increase of plot area should be accompanied by an increase in price by roughly one percent. Our OLS estimations suggest, instead, that the price only increases by 0.8% or less (moreover, the coefficient is somewhat unstable across specifications).

A potential explanation for this under-estimation is the public-good nature of assets that are traded on this market. The land market for natural reserves is a market where assets acquired by non-profits are used to produce public goods. Like in any other land market, buyers exchange money for land plots, and, overall, prices are determined by demand and supply. However, unlike in the usual land markets, buyers also invest substantial effort in convincing sellers to accept a lower price in the interest of the public good (or in prospecting for sellers that are more publicspirited). During our work on data, we collected anecdotal evidence concerning several landowners who were happy to sell their land for a symbolic price, provided that the buyer maintains the landscape and protects endangered animals living in the area. These benefits are non-rival and non-excludable, which means that the seller is sure to enjoy those environmental services without paying a management cost. On the other hand, non-profits are sometimes inclined to pay a relatively high price for a small plot because that plot would allow the extension of a green mesh between sites. Both types of transactions constitute outliers, and failing to take them into account biases the estimates obtained above.

From the econometrics point of view, these transactions constitute vertical outliers for small plots with high prices and bad leverage points for large plots sold at symbolic prices, creating serious issues of heteroscedasticity. The presence of both types of outliers biases regression coefficients downwards and increases standard errors. In specification (6) of Table 4.2, we estimate our model including a dummy variable flagging seven most obvious quasi-donations, i.e. land plots sold for a clearly symbolic price. Four of these transactions occurred before July 1986 and the remaining occurred after. The price-surface elasticity is jumps from 0.75 to 0.82 and the $t$-statistic doubles. The coefficient on the policy dummy drops by about 15 per cent, whereas the $R^2$ reaches 0.72. This implies that correcting for less than one percent of observations has a major influence on our results. Proceeding in such a way would not be problematic if we could easily flag all the transactions with exceptionally low and high prices; however, this is quite cumbersome (given the size of our dataset) and might also involve some arbitrariness in borderline cases.

A better way of attacking this problem is to use an estimator robust to outliers. We opt for the MS-estimator proposed by Maronna and Yohai (2000) and developed by Verardi and Croux (2009). It allows for a robust and efficient estimation in the presence of outliers in a multidimensional setting, deals with dummy variables in the set of explanatory variables, and properly handles asymmetric distribution of residuals in the presence of outliers. The loss function of this estimator is a Tukey-Biweight function in which the marginal change of the residuals' weight tends to 0 as residuals become large. It means that all observations have some weight in the regression but that this weight does not explode when the observation lies far away from the regression line.

Table 4.2 – OLS regression results

| | (1) log of price | (2) log of price | (3) log of price | (4) log of price | (5) log of price | (6) log of price |
|---|---|---|---|---|---|---|
| Bought after the reform | 0.0143 | 0.0238 | 0.0239 | 0.0194 | 0.0884 | 0.0735 |
| | [0.261] | [0.262] | [0.261] | [0.256] | [0.266] | [0.144] |
| Year * reform | -0.0252 | -0.0262 | -0.0265 | -0.0320 | -0.0389 | -0.0113 |
| | [0.0351] | [0.0349] | [0.0356] | [0.0339] | [0.0326] | [0.0226] |
| Year, 17jul1986=0 | 0.0188 | 0.0186 | 0.0194 | 0.0184 | 0.0144 | -0.00431 |
| | [0.0225] | [0.0225] | [0.0224] | [0.0221] | [0.0212] | [0.00884] |
| Log of surface | 0.814*** | 0.812*** | 0.778*** | 0.747*** | 0.750*** | 0.819*** |
| | [0.0783] | [0.0789] | [0.0817] | [0.0790] | [0.0794] | [0.0483] |
| Number of co-owners | | 0.0210 | 0.0146 | 0.0145 | 0.0180 | 0.0000953 |
| | | [0.0212] | [0.0207] | [0.0205] | [0.0209] | [0.0173] |
| Out of core area | | | | 0.431*** | 0.326** | 0.381*** |
| | | | | [0.132] | [0.160] | [0.123] |
| Sold at symbolic price | | | | | | -7.905*** |
| | | | | | | [0.869] |
| CONTROLS | | | | | | |
| Land quality | N | N | Y | Y | Y | Y |
| Buyers identity | N | N | N | N | Y | Y |
| Observations | 938 | 938 | 938 | 938 | 938 | 938 |
| Adjusted $R^2$ | 0.432 | 0.432 | 0.438 | 0.449 | 0.459 | 0.726 |

Standard errors in brackets, clustered at the municipality level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4.3 – MS regression results

| | (1) log of price | (2) log of price | (3) log of price | (4) log of price | (5) log of price | (6) log of price |
|---|---|---|---|---|---|---|
| Bought after the reform | 0.494* | 0.409*** | 0.570*** | 0.575*** | 0.396 | 0.396 |
| | [0.272] | [0.153] | [0.127] | [0.158] | [0.261] | [0.277] |
| Year * reform | -0.0748*** | -0.0841*** | -0.0341** | -0.0354* | -0.0464* | -0.0458* |
| | [0.0221] | [0.0152] | [0.0164] | [0.0189] | [0.0241] | [0.0250] |
| Year, 17jul1986=0 | -0.00535 | 0.000452 | -0.0158** | -0.0159 | -0.00296 | -0.00305 |
| | [0.0195] | [0.00966] | [0.00768] | [0.00981] | [0.0167] | [0.0179] |
| Log of surface | 1.081*** | 1.067*** | 1.034*** | 1.029*** | 1.041*** | 1.041*** |
| | [0.0235] | [0.0310] | [0.0212] | [0.0235] | [0.0255] | [0.0259] |
| Number of co-owners | | -0.0390 | 0.00801 | 0.00877 | 0.00353 | 0.00355 |
| | | [0.0290] | [0.00831] | [0.00941] | [0.0101] | [0.00988] |
| Out of core area | | | | 0.0510 | 0.0396 | 0.0396 |
| | | | | [0.0388] | [0.0450] | [0.0456] |
| Sold at symbolic price | | | | | | -8.211*** |
| | | | | | | [0.220] |
| CONTROLS | | | | | | |
| Land quality | N | N | Y | Y | Y | Y |
| Buyers identity | N | N | N | N | Y | Y |
| Hausman's Chi-squared | 20.66 | 25.51 | 37.75 | 59.89 | 82.85 | 220.9 |
| Observations | 938 | 938 | 938 | 938 | 938 | 938 |

Robust standard errors in brackets

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4.3 reports estimates of the same specifications than those in Table 4.2, with estimations performed using the MS-method. Robust estimation does not affect the signs of coefficients. The elasticity of prices to land surface is now very close to one and is highly stable across specifications. The introduction of the subsidy has an estimated positive effect on prices of an order between 41 and 57 per cent. Therefore, for a plot valued €100, the introduction of the subsidy pushes the price up to €150 (of which €75 are paid by the non-profit recipient of the subsidy). Thus, in the short run the subsidy represents a €25 saving for the non-profit. Over time, the price steadily declines until it reaches the pre-subsidy price around nine years after the introduction of the subsidy. Given that our sample is limited to the eight years following the reform, we cannot know if the trend would have continued until subsidized prices become actually lower than non-subsidized prices or whether it would have stabilized around the trend.

The introduction of the dummy variable indicating quasi-donations in the last specification leaves our estimates virtually unchanged, contrarily to the instability of OLS estimates noted above. The regression coefficient on this dummy is unsurprisingly large, predicting a drop in the price for these plots by more than 99 per cent; however, all other coefficients remain unaffected. This stability is a clear indication that our methodology is justified and that robust estimates adequately depict regular market conditions without being much affected by other mechanisms that drive the outliers. We also report in this table a generalized Hausman test proposed by Dehon et al. (2011). For all estimations, the ordinary least squares method (an efficient but potentially inconsistent estimation technique) systematically provides estimators which are significantly different from robust ones. Despite a somewhat lower efficiency of the MS-methodology (28.4 per cent loss in efficiency), it seems reasonable to prefer the consistent robust estimation technique.

In the Appendix, we provide three further tables with robustness checks. Table 4.4 reports estimates based on the outlier-free subsample of the first five specifications of Table 4.2. Point estimates of the main coefficients of interest are slightly lower in absolute value than robust estimates on the full sample; however, all the results go in the same direction. Estimates of price-surface elasticity are remarkably stable. Table 4.3 introduces several variations in the model specification. The first column corresponds to the baseline specification estimated by the MS-estimator. The second column allows for a more flexible relationship between the price and the time trend by introducing quadratic terms in the trend. The estimated effect of the policy reform is smaller and less precisely estimated but remains economically significant. The third column reports estimates on a subsample generated by eliminating all land purchases made between January 1985 and July 1986 (i.e. transactions potentially affected by anticipating the reform). Point estimates of the coefficient on the reform dummy increases a little bit; which could indicate some (minor) anticipation of the reform. Specification (4) introduces another modification to check that the anticipation effect does not seriously affect our estimations. In this specification, we set the timing of the policy reform on January 1, 1985: this eliminates the distinction between the starting date of the retroactive effect of the reform and the date of the reform itself. Estimates remain similar in terms of the signs and sizes of coefficients, and inference is not affected much. Finally, in the specification in the last column, we impose an extremely conservative restriction on our sample: we consider only the 75 transactions preceding January 1, 1985 and the 75 transactions immediately following the policy reform. We comfortingly find effects similar to those found for the full sample, with slightly larger standard errors (despite the relatively low statistical power caused by our sample restriction), consistently with our previous findings. Table 4.6 confirms the results of a the MS estimation in a linear specification, finding qualitatively identical results.

Our identification is based on the policy break in 1986 and on comparing the land plots with similar characteristics acquired by the non-profits before and after the reform. However, it is possible that other changes in the environment of the market for land might have occurred around the same time. For instance, if other policy changes that concerned all the agricultural land in the region were introduced shortly before or after the subsidy, one would observe a pattern similar to the one that we find, but it would be driven (at least in part) by these other policy changes. In that case, our findings would be a poor test of the theory presented above.

To allay this concern, we have collected the data on the aggregate land market prices for two major types of land: woodland and farm land/pastures. The markets for these types of land are of an order of magnitude larger as compared to the market for the land that non-profits acquire. Crucially, a very small proportion of these types of land could qualify for the 1986 subsidy. The time series of prices comes from the

Belgian National Statistics Agency (INS, 1994), and represents average prices per hectare (from all land transactions, by type, which are officially registered).

Figure 4.6 – Evolution of prices for different land types

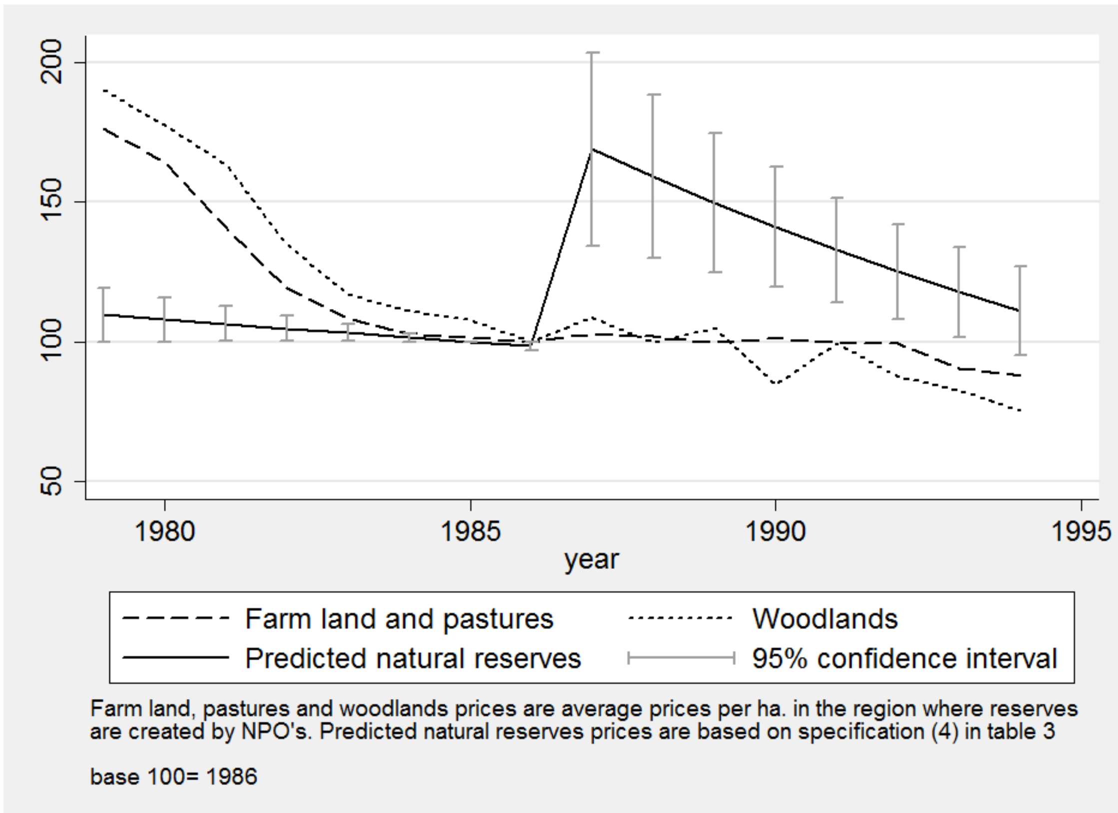



Figure 4.6 plots the evolution of land prices in the Walloon region, from 1979 until 1994. It depicts three series: the average price per hectare of woodlands, the average price per hectare of farmland and pastures, and the predicted price per hectare of land acquired by non-profits (constructed on the basis of our notary-deeds data). For clarity, we have normalized the prices, with 1986 (the year of the reform) being the baseline. One clearly sees that there is not a break around 1986 in prices of woodlands and farm lands, at least not of a magnitude comparable to the predicted natural reserve land prices. Following the pattern that we have documented above, we see that prices of land prices purchased by non-profits first jumps, and then converges in the long-term to the initial level).

## 4.5 Discussion

### 4.5.1 Interpretation of empirical results

Our theoretical model has generated two testable propositions. Proposition 4.2 predicts a the differential effect of the subsidy over time: we should observe that prices of assets bought by non-profits strongly increase in the short-run and then decrease in the long-run as compared to this short-run peak; the quantity of assets bought should increase unambiguously over time. Above, we have tested this prediction using data on land acquisitions by environmental non-profits in the Walloon region of Belgium. Properly taking into account the presence of outliers in the data (both vertical ones and bad leverage points) by using the MS-estimator, we show that the empirical results are in line with this first prediction of our theoretical framework. All the parts of Proposition 4.2 are confirmed: we observe a spike in prices just after the introduction of the subsidy (i.e. $\alpha_1 > 0$), followed by a progressive decline towards the initial price ($\alpha_3 < 0$). Even if the effect of the subsidy on the market price vanishes over time, the number of transactions largely increases by the end of the sample period, as shown in Figure 3. This is fully consistent with a positive demand shock followed with a long-run expansion of the supply curve.

Corollary 4.1 predicts a differential effect of the subsidy across non-profit types. In particular, one should observe a relatively stronger increase in land purchases by non-profits that give a relatively higher weight to the quantity than to the quality of public goods provided (captured by the parameter $\alpha_i$ in our model). In our data, the two main non-profits have different preferences in the quantity versus quality trade-off; these differences are made clear when one looks at their mission statements. The mission statement of the first organization (*Ardenne & Gaume*) reads:

> "[The association] has the objective of creating (and participating to the creation) and managing (and participating to the management of) natural reserves [...] and more generally of any structure, private or public, regardless of its form, that contributes to preserving nature."

For the second organization (*R.N.O.B.*), one reads:

> "[The association] is devoted to preserving and managing threatened natural habitats. To this end, the association develops a strategy of pur-

> chasing or renting land with considerable biological interest, mainly in the Walloon and Brussels regions."

The first non-profit seems to be more open to partnerships and its mission statement mostly emphasizes natural reserve management efforts. Contrarily, the second statement makes clear that the organization's priority is on purchasing land. As displayed in Figure 4.3, we can see that the second non-profit (*R.N.O.B.*) is purchasing the largest number of land plots (in terms of total surface) after the reform. The market share of each of the two non-profits changes following the introduction of the subsidy in the direction predicted by our model. Consequently, the subsidy makes the quantity-driven non-profit capture virtually all the new land purchases.

This change in the market structure is consistent with corollary 4.1. In a market with relatively few actors, one should observe that the subsidy has a relatively small effect on the long-run price and a relatively large effect on the quantity purchased, at the expense of less effort devoted to quality enhancement. Given that our empirical analysis focuses on only one market, we cannot compare its outcomes to those of a less concentrated market. However, combined with information about the context that we have discussed above, it is clear that the de facto monopsony position of the R.N.O.B., driven by its quantity-oriented mission, induced it to engage massively in supply-expanding prospecting activities, avoiding the free-riding that would plague a market with multiple small prospecting non-profits. Under these conditions, the long-run impact of the ad valorem subsidy in such a concentrated market had a huge impact on quantities of land purchased, as we have shown previously.

Policy-wise, the relatively limited effect on prices and the long-run convergence towards the pre-reform trend, combined with the large expansion in quantity purchased might seem a positive result, given that large amounts of land were traded without a massive price pass-through effect of taxpayers' money to private sellers. However, a caveat should be mentioned. As we have argued above, the less aggressive quality-oriented buyers are driven out of the market and the market is dominated by organizations that consider quantity purchased to be the priority. A negative effect of the subsidy is that quality-enhancing management effort per unit of land is predicted to decrease. Therefore, the ad valorem subsidy encouraging private ownership of public goods is an efficient policy tool only if the quantity of the public good (and not its quality) is the policy objective.

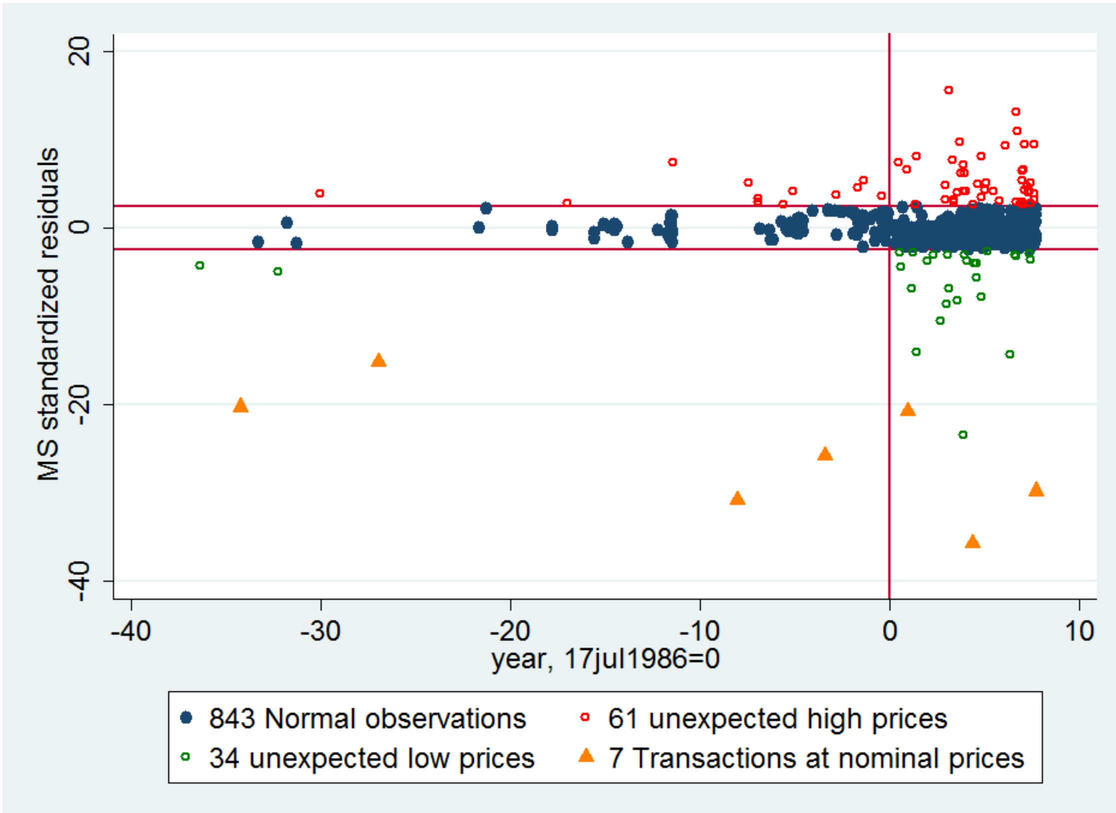
### 4.5.2 Econometric methodology

In our empirical investigation we implicitly assume that (at least) two different data-generating processes (DGPs) generated our sample. This assumption is supported by the anecdotal evidence collected during our data construction. A part of transactions on the land market for natural reserves does not fit the classical supply-and-demand framework. Some transactions are non-standard in the sense that public-good considerations, warm-glow and persuasion play a key role in shaping the prices. Our data are thus "contaminated" by these observations with potentially abnormally low prices. It is, however, impossible to disentangle the DGP of each observation *a priori*. Identification of other DGPs requires additional information (not observed, and, in some cases, unobservable). This lack of information can be overcome by using robust estimation techniques that allow to consistently estimate the main DGP. We opt for the MS-estimator for four reasons: (1) it is robust to good and bad leverage points; (2) it allows for asymmetries in outliers distribution; (3) it allows to handle categorical variables; and (4) it has a very low break-down point of 50 per cent (i.e. the estimated coefficients are consistent even when almost half of the sample is contaminated by outliers).

Once the coefficients behind the main DGP are estimated, one can consistently identify the outliers in the data as shown for instance in Figure 4.7. Importantly, the identification process relies on an objective statistical procedure rather than on the *a priori* of the researcher, and in case one is interested in understanding the origin of the outliers in one's data, this procedure offers a systematic basis for the case-study analysis of outliers.

More generally, this methodology might be useful in settings where different DGPs might coexist and where other tools to grasp their co-existence are missing (provided that one DGP generates at least half of the data points). We believe that our method has numerous potential applications in the empirical analyses of non-profit sector, given that the theoretical literature agrees that the behaviour of various actors in this sector (donors, managers, volunteer workers, etc.) is driven by a mix of classic extrinsic high-powered incentives and intrinsic motivation (see, e.g., Benabou and Tirole (2003); Tirole and Bénabou (2006); Besley and Ghatak (2005)). Standard estimation techniques might miss this co-existence of DGPs and lead to inconsistent estimates.

Figure 4.7 – Outliers in specification 4 of table 4.3




## 4.6 Conclusion

What are the broader implications of our model and empirical findings? The framework of analysis that we have developed above applies to a large set of contexts where the provision of a public good is delegated to a non-profit organization. These are the contexts in which a certain asset or input potentially can generate substantial externalities or has a fundamental public-good nature, but is initially held by a private party that value insufficiently these externalities. At the same time, there exist agents (or organizations founded by such agents) that are intrinsically motivated and would like to internalize these externalities or release the public-good potential of the asset. Usually, however, these agents are credit-constrained (or, more generally, cannot easily monetize their intrinsic motivation; so their willingness-to-pay does not fully reflect their motivation). Thus, they can either raise funds through solicitations from other agents, or the government can assist in transferring the ownership of the asset to these motivated agents. Moreover, locating such assets implies a positive search cost.

One example of such a setting (beyond environmental conservation discussed above) is the market for art. Most private non-profit organizations devoted to artistic or cultural heritage conservation face the problem similar to the one discussed in our paper: works of art are often held by individuals that do not fully value their public-good nature, and such objects are traded in a competitive market. Government can subsidize the acquisition by non-profit museums of these works of art, but finding the art pieces that best suit the collection of the non-profit museum requires effort.

Another example is the non-profit organizations whose mission is to combat environmental pollution by, for example, recycling polluting second-hand appliances. There exists (relatively thin) markets for these objects. Some appliances are more polluting than others (e.g. they contain highly environmentally-hazardous substances); however, given the absence of monetary incentives, some owners are unlikely to be willing to pay the cost of bringing them to the recycling points. Thus, the non-profits often conduct the door-to-door campaigns of searching for such appliances, which requires substantial effort. From the policy perspective, it is important to investigate the desirability of government subsidies for the purchase of such appliances by non-profits.

In addition, our empirical analysis has an important methodological implication. In applied problems of evaluating the effects of government subsidies on the market outcomes in this kind of settings, a non-negligible fraction of data points exhibit very low prices. This occurs because some of the initial owners of the assets can also be intrinsically motivated, and these owners would sell these assets to non-profits for a price that does not correctly reflect the market value of the assets (i.e. a symbolic price). In that case, failing to treat such outliers properly might induce the researcher to underestimate the effect of the subsidy on the market price and to overestimate the effect on the quantity. Our analysis above highlights such pitfalls and illustrates the appropriate robust methodology for treating these outliers.

## 4.7 Appendix

### 4.7.1 Resolution of the Lagrangian

$$\mathcal{L}(q_t^i, x_t^i, n_t^i, f_t^i, \lambda_t^i, \nu_t^i) = q_t^i x_t^{i\omega^i} - \lambda_t^i \left[(1-\sigma)\left(\frac{q_t^i}{n_t^i}\right)^2 - \mu f_t^i\right] - \nu_t^i(v_t^i - x_t^i - f_t^i - n_t^i)$$

First order conditions:

**wrt** $q_t^i$ **:**

$$x_t^{i\omega^i} = \lambda_t^i\ (1-\sigma)2\frac{q_t^i}{n_t^{i2}} \tag{4.9}$$

**wrt** $x_t^i$ **:**

$$\omega^i q_t^i x_t^{i\omega^i - 1} = \nu_t^i \tag{4.10}$$

**wrt** $n_t^i$ **:**

$$\lambda_t^i(1-\sigma)2\frac{q_t^{i2}}{n_t^{i3}} = \nu_t^i \tag{4.11}$$

**wrt** $f_t^i$ **:**

$$\lambda_t^i \mu = \nu_t^i \tag{4.12}$$

**wrt** $\lambda_t^i$ **:**

$$(1-\sigma)\left(\frac{q_t^i}{n_t^i}\right)^2 = \mu f_t^i \tag{4.13}$$

**wrt** $\mu_t^i$ **:**

$$v_t^i = x_t^i + f_t^i + n_t^i \tag{4.14}$$

Use (4.12) to replace all $\nu_i^t$ by $\lambda_t^i\mu$ . The ratio (4.9)/(4.10) yields

$$x_t^i = \omega^i 2\frac{1-\sigma}{\mu}\left(\frac{q_t^i}{n_t^i}\right)^2 \tag{4.15}$$

(4.11) can be rearranged to :

$$n_t^i = 2\frac{1-\sigma}{\mu}\left(\frac{q_t^i}{n_t^i}\right)^2 \tag{4.16}$$

(4.13) can be rearranged to :

$$f_t^i = \frac{1-\sigma}{\mu}\left(\frac{q_t^i}{n_t^i}\right)^2 \tag{4.17}$$

Plugging back the three previous equations in (4.14) obtains :

$$v_t^i = (3+2\omega^i)\frac{1-\sigma}{\mu}\left(\frac{q_t^i}{n_t^i}\right)^2 \tag{4.18}$$

Combining (4.15) and (4.18) we obtain

$$x_t^{i*} = \frac{2\omega^i}{3+2\omega^i}v_t^i$$

Combining (4.16) and (4.18) we obtain

$$n_t^{i*} = \frac{2}{3+2\omega^i}v_t^i \tag{4.19}$$

Combining (4.17) and (4.18) we obtain

$$f_t^{i*} = \frac{1}{3+2\omega^i}v_t^i$$

Using (4.18) and (4.19) one obtains :

$$q_t^{i*} = 2\left(\frac{v_t^i}{3+2\omega^i}\right)^{3/2}\left(\frac{\mu}{1-\sigma}\right)^{1/2} \tag{4.20}$$

Finally, by using (4.1) the equilibrium price paid by $i$ is:

$$p_t^{i*} = \sqrt{\frac{(3+2\omega^i)\mu}{(1-\sigma)v_t^i}} \tag{4.21}$$

### 4.7.2 Details on the motion of volunteer hours

From any initial state $v_0^i$ we obtain

$$
\begin{aligned}
v_1^i &= \frac{2}{3}\left[\frac{\mu}{(3+2\omega^i)(1-\sigma)}v_0^i\right]^{\frac{1}{2}} \\
v_2^i &= \left[\frac{2}{3}\left[\frac{\mu}{(3+2\omega^i)(1-\sigma)}\right]^{\frac{1}{2}}\right]^{\frac{1}{2}} {v_0^i}^{\frac{1}{2^2}} \\
&\dots \\
v_t^i &= \left[\frac{2}{3}\left[\frac{\mu}{(3+2\omega^i)(1-\sigma)}\right]^{\frac{1}{2}}\right]^{\Sigma_{\tau=0}^{\tau=t-1}\frac{1}{2^t}} {v_0^i}^{\frac{1}{2^t}}
\end{aligned}
\tag{4.22}
$$

Because $\Sigma_{\tau=0}^{\tau=t-1}\frac{1}{2^t} = \dfrac{1-\frac{1}{2^t}}{1-\frac{1}{2}} = 2-2^{1-t}$ , we obtain

$$
v_t^i = \left[\frac{2}{3}\left[\frac{\mu}{(3+2\omega^i)(1-\sigma)}\right]^{\frac{1}{2}}\right]^{2-2^{1-t}} {v_0^i}^{2^{-t}}
$$

### 4.7.3 Additional tables

Table 4.4 – OLS regression results, without outliers

| | (1) log of price | (2) log of price | (3) log of price | (4) log of price | (5) log of price |
|---|---|---|---|---|---|
| Bought after the reform | 0.266* | 0.240* | 0.271** | 0.267** | 0.250* |
| | [0.135] | [0.135] | [0.116] | [0.118] | [0.129] |
| Year * reform | -0.0432*** | -0.0463*** | -0.0344** | -0.0361*** | -0.0425*** |
| | [0.0138] | [0.0140] | [0.0139] | [0.0134] | [0.0135] |
| Year, 17jul1986=0 | -0.00358 | -0.00183 | -0.00575 | -0.00624 | -0.00365 |
| | [0.00726] | [0.00724] | [0.00634] | [0.00637] | [0.00768] |
| Log of surface | 1.064*** | 1.063*** | 1.047*** | 1.030*** | 1.035*** |
| | [0.0177] | [0.0182] | [0.0174] | [0.0140] | [0.0129] |
| Number of co-owners | | -0.0180** | -0.0126 | -0.0130 | -0.0141 |
| | | [0.00738] | [0.00850] | [0.00867] | [0.00876] |
| Out of core area | | | | 0.218** | 0.163* |
| | | | | [0.0903] | [0.0885] |
| CONTROLS | | | | | |
| Land quality | N | N | Y | Y | Y |
| Buyers identity | N | N | N | N | Y |
| Observations | 844 | 846 | 843 | 843 | 843 |
| Adjusted $R^2$ | 0.923 | 0.922 | 0.923 | 0.926 | 0.931 |

Standard errors in brackets, clustered at the municipality level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4.5 – Alternative specifications in MS-regressions

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | log of price | log of price | log of price | log of price | log of price |
| Bought after the | 0.575*** | 0.251 | 0.636*** | | 0.404*** |
| reform (Jul. 1986) | [0.158] | [0.201] | [0.0934] | | [0.121] |
| Year * order | -0.0354* | -0.0302 | -0.0290** | | -0.0590 |
| | [0.0189] | [0.0549] | [0.0139] | | [0.0372] |
| Year, 17jul1986=0 | -0.0159 | 0.0219 | -0.0198*** | | 0.00373 |
| | [0.00981] | [0.0257] | [0.00524] | | [0.0135] |
| Year squared | | 0.00122 | | | |
| | | [0.000762] | | | |
| Year squared* reform | | -0.00736 | | | |
| | | [0.00803] | | | |
| Bought after the | | | | 0.632*** | |
| reform (Jan. 1985) | | | | [0.0919] | |
| Year * reform | | | | -0.0211* | |
| | | | | [0.0114] | |
| Year, 1jan1985=0 | | | | -0.0197*** | |
| | | | | [0.00541] | |
| Log of surface | 1.029*** | 1.035*** | 1.023*** | 1.020*** | 0.918*** |
| | [0.0235] | [0.0234] | [0.0188] | [0.0184] | [0.0455] |
| Number of co-owners | 0.00877 | 0.00589 | 0.00945 | 0.00884 | -0.0242 |
| | [0.00941] | [0.0149] | [0.00780] | [0.00859] | [0.0162] |
| Out of core area | 0.0510 | 0.0657 | 0.0547 | 0.0565 | 1.015*** |
| | [0.0388] | [0.0425] | [0.0370] | [0.0363] | [0.165] |
| CONTROLS | | | | | |
| Land quality | Y | Y | Y | Y | Y |
| Buyers identity | N | N | N | N | N |
| Hausman's Chi-squared | 59.89 | 56.41 | 55.52 | 58.26 | 45.74 |
| Observations | 938 | 938 | 917 | 938 | 150 |
| Sample | Full | Full | Full$\setminus$ [1985; 17$Jul$86] | Full | [−75; +75] $\setminus$ [1985; 17$Jul$86] |
| Timing of the break | 17Jul1986 | 17Jul1986 | 01Jan1985 | 17Jul1986 | 17Jul1986 |

Robust standard errors in brackets

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4.6 – Alternative specifications in MS-regressions, evaluated at price levels

| | (1) price | (2) price | (3) price | (4) price | (5) price | (6) price |
|---|---|---|---|---|---|---|
| Bought after the reform | 431.3*** | 413.5*** | 397.6*** | 390.8*** | 385.5*** | 390.2*** |
| | [84.77] | [82.46] | [83.23] | [82.13] | [80.96] | [79.29] |
| Year * reform | 1.106 | 2.056 | 3.267 | 3.409 | 3.369 | 2.401 |
| | [5.487] | [5.272] | [5.795] | [5.762] | [5.590] | [5.234] |
| Year, 17jul1986=0 | -72.40*** | -72.52*** | -68.12*** | -71.02*** | -69.63*** | -67.27*** |
| | [9.542] | [9.419] | [9.886] | [9.895] | [10.48] | [10.16] |
| Surface | 3610.3*** | 3609.6*** | 3616.8*** | 3615.3*** | 3617.7*** | 3616.4*** |
| | [4.967] | [5.102] | [5.300] | [4.945] | [5.858] | [5.605] |
| Number of co-owners | | -25.26** | -23.40** | -25.10** | -28.18** | -28.04** |
| | | [12.30] | [11.75] | [11.66] | [12.34] | [12.26] |
| Out of core area | | | | 178.3*** | 160.7*** | 161.6*** |
| | | | | [38.46] | [44.47] | [44.18] |
| Sold at symbolic price | | | | | | -447.9*** |
| | | | | | | [129.8] |
| CONTROLS | | | | | | |
| Land quality | N | N | Y | Y | Y | Y |
| Buyers identity | N | N | N | N | Y | Y |
| Hausman's Chi-squared | 20.66 | 25.51 | 37.75 | 59.89 | 82.85 | 220.9 |
| Observations | 938 | 938 | 938 | 938 | 938 | 938 |

Robust standard errors in brackets

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Chapter A

# Semiparametric Fixed-Effects Estimator

François Libois and Vincenzo Verardi

**Abstract** [1]

This paper describes the Stata implementation of Baltagi and Li's (2002) series estimator of partially linear panel data models with fixed effects. After a brief description of the estimator itself, we describe the new command `xtsemipar`. We then simulate data to show that this estimator performs better than a fixed effect estimator if the relationship between two variables is unknown or quite complex.

*Keywords:*
`xtsemipar`, semiparametric estimations, panel data, fixed effects

*JEL Classification*:
C14, C21

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## A.1 Introduction

The objective of this note is to present a Stata implementation of Baltagi and Li (2002)'s series estimation of partially linear panel data models.

The structure of the note is the following: section 2 describes Baltagi and Li (2002)'s fixed effects semiparametric regression estimator. Section 3 presents the implemented Stata command (**xtsemipar**). Some simple simulations assessing the performance of the estimator are shown in Section 4. Section 5 provides a conclusion.

## A.2 Estimation method

### A.2.1 Baltagi and Li (2002) semiparametric fixed effects regression estimator

Consider a general panel data semiparametric model with distributed intercept of the type:

$$y_{it} = \mathbf{x}_{it}\theta + f(z_{it}) + \alpha_i + \varepsilon_{it}, \quad i = 1, ..., N; t = 1, ..., T \text{ where } T << N \tag{A.1}$$

To eliminate the fixed effects $\alpha_i$, a common procedure, inter alia, is to differentiate (A.1) over time which leads to

$$y_{it} - y_{it-1} = (\mathbf{x}_{it} - \mathbf{x}_{it-1})\theta + [f(z_{it}) - f(z_{it-1})] + \varepsilon_{it} - \varepsilon_{it-1} \tag{A.2}$$

An evident problem here is to consistently estimate the unknown function of $z \equiv G(z_{it}, z_{it-1}) = [f(z_{it}) - f(z_{it-1})]$. What Baltagi and Li (2002) propose is to approximate $f(z)$ by series $p^k(z)$ (and therefore approximate $G(z_{it}, z_{it-1}) = [f(z_{it}) - f(z_{it-1})]$ by $p^k(z_{it}, z_{it-1}) = [p^k(z_{it}) - p^k(z_{it-1})]$) where $p^k(z)$ are the first $k$ terms of a sequence of functions $(p_1(z), p_2(z), ...)$. They then demonstrate the $\sqrt{N}$ normality for the estimator of the parametric component (i.e., $\hat{\theta}$) and the consistency at the standard non-parametric rate of the estimated unknown function (i.e., $\hat{f}$). The equation (A.2) therefore boils down to

$$y_{it} - y_{it-1} = (\mathbf{x}_{it} - \mathbf{x}_{it-1})\theta + [p^k(z_{it}) - p^k(z_{it-1})]\gamma + \varepsilon_{it} - \varepsilon_{it-1} \tag{A.3}$$

which can be consistently estimated by using ordinary least squares. Having estimated $\hat{\theta}$ and $\hat{\gamma}$, we propose to fit the fixed effects $\hat{\alpha}_i$ and go back to (A.1) to estimate the error component residual

$$\hat{u}_{it} = y_{it} - \mathbf{x}_{it}\hat{\theta} - \hat{\alpha}_i = f(z_{it}) + \varepsilon_{it}. \tag{A.4}$$

The curve $f$ can be fitted by regressing $\hat{u}_{it}$ on $z_{it}$ using some standard non-parametric regression estimator.

A typical example of $p^k$ series is spline which is a fractional polynomial with pieces defined by a sequence of knots $c_1 < c_2 < ... < c_k$ where they join smoothly.

The simplest case is a linear spline. For a spline of degree $m$ the polynomials and their first $m-1$ derivatives agree at the knots, so that $m-1$ derivatives are continuous (see Royston and Sauerbrei (2007) for further details).

A spline of degree $m$ with $k$ knots can be represented as a power series:

$$S(z) = \sum_{j=0}^{m} \theta_j z^j + \sum_{j=1}^{k} \lambda_j (z - c_j)_+^m \text{ where } (z - c_j)_+^m = \begin{cases} z - c_j \text{ if } z > c_j \\ 0 \text{ otherwise} \end{cases}$$

The problem here is that successive terms tend to be highly correlated. A probably better representation of splines is a linear combinations of a set of basic splines called (k$^{th}$ degree) B-splines which are defined, for a set of $k+2$ consecutive knots $c_1 < c_2 < ... < c_{k+2}$ as

$$B(z, c_1 ... c_{k+2}) = (k+1) \sum_{j=1}^{k+2} \left[ \prod_{1 \leq h \leq k+2, h \neq j} (c_h - c_j) \right]^{-1} (z - c_j)_+^k$$

B-splines are intrinsically a rescaling of each of the piecewise functions. The technicalities of this method are beyond the scope of this paper and we refer the reader to Newson (2001) for further details.

We implemented this estimator in Stata under the command **xtsemipar**. We describe the command here below.

## A.3 The xtsemipar command

The **xtsemipar** command fits Baltagi and Li's double series fixed-effects estimator in the case of one single variable entering the model nonparametrically. Running the **xtsemipar** command requires the prior installation of the **bspline** module developed by Newson (2000).

The general syntax for the command is:

`xtsemipar` *varlist* [`if`] [`in`] [`weight`], `nonpar`(*varname*) [`generate`([*string1*] *string2*) `degree`(#) `knots1`(*numlist*) `nograph` `spline` `knots2`(*numlist*) `bwidth`(#) `robust` `cluster`(*varname*) `ci` `level`(#)]

The first option, `nonpar`, is mandatory. It declares which variable enters the model nonparametrically. None of the remaining options are compulsory. The user has the opportunity to recover the error component residual - the left hand side of equation (A.4) - whose name can be chosen by specifying *string2*. This error component can then be used to draw any kind of nonparametric regression. Since the error component has already been partialled out from fixed effects and from the parametrically dependent variables, this amounts to estimating the net nonparametric relation between the dependent and the variable that enters the model nonparametrically. By default, `xtsemipar` reports one estimation of this net relationship. *string1* makes it possible to reproduce the values of the fitted dependent variable. It is worth noting that the plot of residuals is re-centered around its mean. The remaining part of this section describe options that affect this fit.

A key option in the quality of the fit is `degree`. It determines the power of the B-splines that are used to consistently estimate the function resulting from the first difference of $f(z_{it})$ and $f(z_{it-1})$ functions. By default it is set to 4. If the `nograph` option is not specified, i.e. the user wants the graph of the nonparametric fit of the variable in `nonpar` to appear, `degree` will also determine the degree of the local weighted polynomial fit used in the epanechnikov kernel performed at the last stage fit. If `spline` is specified, this last nonparametric estimation will also be estimated by the B-spline method and `degree` is then the power of these splines. `knots1` and `knots2` are both rarely used. They define a list of knots where the different pieces of the splines agree. If left unspecified, the number and location of the knots will be chosen optimally, which is the most common practice. `knots1` refers to the B-spline estimation in A.3. `knots2` can only be used if the `spline` option is specified and refers to the last stage fit. More details about B-spline can be found in Newson (2001). The `bwidth` option can only be used if `spline` is not specified. It gives the half-width of the smoothing window in the epanechnikov-kernel estimation. If left unspecified, a rule-of-thumb bandwidth estimator is calculated and used (see `lpoly` for more details).

The remaining options refer to the inference. The `robust` and `cluster` options correct the inference respectively for heteroskedasticity and for clustering of error terms. In the graph, confidence intervals can be displayed by a shaded area around the curve of fitted values by specifying the option `ci`. Confidence intervals are set to 95% by default, however it is possible to modify them by setting a different confidence level through the `level` option. This affects the confidence intervals both in the nonparametric and in the parametric part of estimations.

## A.4 Simulation

In this section we show, by using some simple simulations, how `xtsemipar` behaves in finite samples. At the end of the section we illustrate how this command can be extended to tackle some endogeneity problems.

In brief, the simulation setup is a standard fixed-effects panel of 200 individuals over 5 time periods (1,000 observations). For the design space, four variables $x_1$, $x_2$, $x_3$ and $d$ are generated from a Normal distribution with mean $\mu = (0, 0, 0, 0)$ and variance-covariance matrix:

$$\begin{array}{cc} & \begin{array}{cccc} x_1 & x_2 & x_3 & d \end{array} \\ \begin{array}{c} x_1 \\ x_2 \\ x_3 \\ d \end{array} & \begin{pmatrix} 1 & & & \\ 0.2 & 1 & & \\ 0.8 & 0.4 & 1 & \\ 0 & 0.3 & 0.6 & 1 \end{pmatrix} \end{array}$$

Variable $d$ is categorized in such a way that five individuals are identified by each category of $d$. In practice we generate these variables in a two-step procedure where $x$'s have two components. The first one is fixed for each individual and is correlated with $d$. The second one is a random realization for each time period.

Table A.1 – Comparison between `xtsemipar` and `xtreg`

| | Bias $x_1$ | Bias $x_2$ | MSE $x_1$ | MSE $x_2$ |
|---|---|---|---|---|
| `xtsemipar` with nonparametric control for $x_3$ | -0.0006 | -0.0007 | 0.00536 | 0.00399 |
| `xtreg` with linear control for $x_3$ | -0.2641 | 0.03752 | 0.07383 | 0.00462 |
| `xtreg` with $2^{nd}$ and $3^{rd}$ order polynomial control for $x_3$ | -0.0023 | -0.0009 | 0.00410 | 0.00321 |

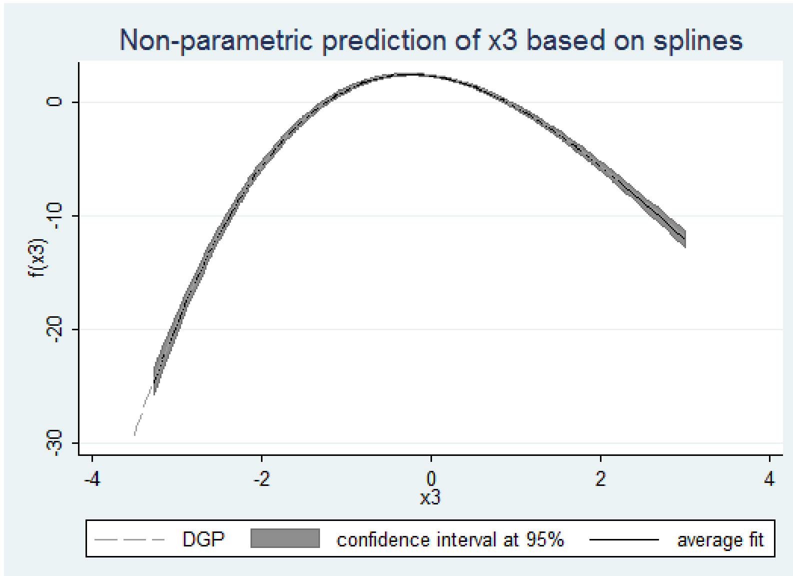
500 replications are carried-out and for each replication an error term e is drawn from a $N(0, 1)$. The dependent variable $y$ is generated according to DGP: $y = x_1 + x_2 - x_3 - 2 * x_3^2 - 0.25 * x_3^3) + d + e$. As it is obvious from this estimation setting, multivariate regressions with individual fixed effects should be used if we want to consistently estimate the parameters. So, we regress $y$ on the $x$'s by using three regression models.

1. `xtsemipar` considering that $x_1$ and $x_2$ enter the model linearly and $x_3$ non-parametrically.
2. `xtreg` considering that $x_1$, $x_2$ and $x_3$ enter the model linearly.
3. `xtreg` considering that $x_1$ and $x_2$ enter the model linearly whereas $x_3$ enters the model parametrically with the correct polynomial form (i.e. $x_3^2$ and $x_3^3$).

Table 1 reports the bias and mean squared error (MSE) of coefficients associated with $x_1$ and $x_2$ for the three regression models. What we find is that Baltagi and Li's (2002) estimator performs much better than the usual fixed effect estimator with linear control for $x_3$, both in terms of bias and efficiency. As expected, the most efficient and unbiased estimator remains the fixed effect estimator with the appropriate polynomial specification. However this specification is generally unknown. Figure 1 displays the average non-parametric fit of $x_3$ (plain line) obtained in the simulation with the corresponding 95% band. The true DGP is represented by the dotted line.

If we want efficient and consistent estimates of parameters, estimations relying on the correct parametric specification are always better. Nevertheless, this correct form has to be known. It could be argued that a sufficiently flexible polynomial fit could be preferable than to a semi-parametric model. This is however not the case. Indeed let's consider the same simulation setting described above, but now the dependent variable $y$ is created according to the new DGP $y = x_1 + x_2 + 3sin(2.5x_3) + d + e$. Figure 2 reports the average non-parametric fit of $x_3$ in a black solid line, with a 95% confidence band around it. The dotted grey line represents the true DGP which

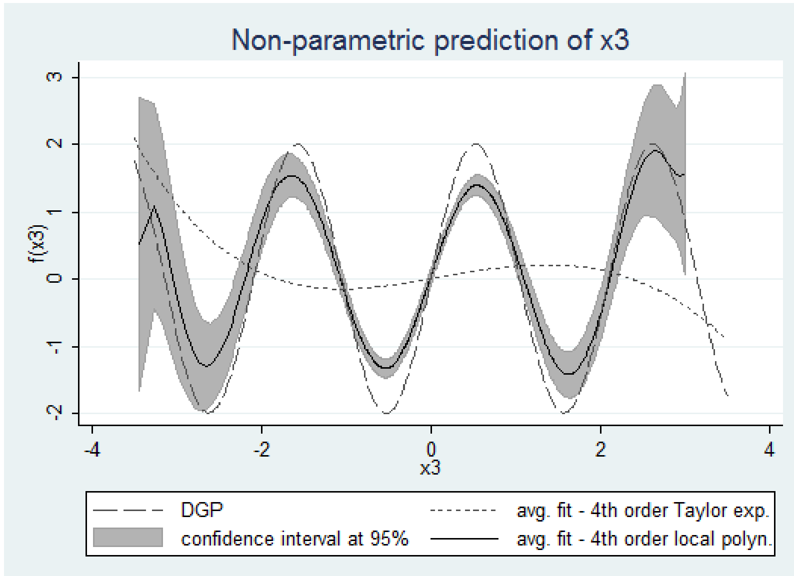
Figure A.1 – Average semi-parametric fit of $x_3$




is quite close to the average fit estimated by `xtsemipar` using a $4^{th}$ order kernel regression with a bandwith set to 0.2. The dashed grey line is the average $4^{th}$ order polynomial fixed-effects parametric fit. As it is clear from this figure, `xtsemipar` provides a much better fit for this quite complex DGP. `xtsemipar` can also ease up the identification of the relevant parametric form and avoid some trial and error that applied researchers often face.

In much of the empirical research in applied economics, measurement errors, omitted variable bias and simultaneity are common issues that can be solved through IV estimation. Baltagi and Li (2002) extend their results to address this kind of problems and establish the asymptotic properties for a partially linear panel data model with fixed effects and possible endogeneity of the regressors. In practice, our estimator can be used within a two-step procedure to obtain consistent estimates of the $\beta$'s. In the first stage, the right-hand side endogenous variable has to be regressed (and fitted) by using (at least) one valid instrument. It should be noted that at this stage of the procedure, the non-parametrical variable linearly enters into the estimation procedure. In the second stage, the semi-parametric fixed effect panel data model can be used to estimate the relation between the dependent variable and the set of regressors. The non-parametrical variable now enters the model nonparamet-

Figure A.2 – Average semi-parametric fit of $x_3$




rically, exactly as explained before. If the instrument is valid, this procedure leads to consistent estimations.

Another problem can arise if the non-parametrical variable is subject to endogeneity problems. In this case, we suggest, as first step of the estimation procedure, using a control functional approach as explained by Ahamada and Flachaire (2008). However we believe that the technicalities associated to this method go well beyond the scope of this note.

## A.5 Conclusion

In econometrics, semiparametric regression estimators are becoming standard tools for applied researchers. In this paper, we present Baltagi and Li (2002) series semiparametric fixed effects regression estimator. We then introduce the Stata codes we created to put it into practice. Some simple simulations to illustrate the usefulness and the performance of the procedure are also shown.

# Bibliography


Abadie, A. and Gardeazabal, J. (2003). The economic cost of conflict: a case study of the Basque country. *American Economic Review*, 93:113–132.

Adhikari, B., Di Falco, S., and Lovett, J. C. (2004). Household characteristics and forest dependency: evidence from common property forest management in Nepal. *Ecological Economics*, 48(2):245–257.

Agrawal, A. (1994). Rules, rule making and rule breaking: Examining the fit between rule systems and resource use. In Ostrom, E., Gardner, R., and Walker, J., editors, *Rules, games and common-pool resources*, pages 267–282. University of Michigan Press, Ann Arbor, Michigan.

Ahamada, I. and Flachaire, E. (2008). *Économétrie non paramétrique*. Economica.

Aldashev, G. and Verdier, T. (2010). Goodwill bazaar: NGO competition and giving to development. *Journal of Development Economics*, 91(1):48–63.

Amacher, G. S., Hyde, W. F., and Kanel, K. R. (1996). Household fuelwood demand and supply in Nepal's tarai and Mid-Hills: Choice between cash outlays and labor opportunity. *World Development*, 24(11):1725 – 1736.

Antoniadou, E., Koulovatianos, C., and Mirman, L. J. (2013). Strategic exploitation of a common-property resource under uncertainty. *Journal of Environmental Economics and Management*, 65(1):28–39.

Arnold, J. and Campbell, C. (1986). Collective management of hill forest in Nepal: The community forestry development project. In Council, N. R., editor, *Proceedings of the conference on common property resource management*, pages 425–454, Washington, DC. National Academy Press.

Arnold, J. M., Kohlin, G., and Persson, R. (2006). Woodfuels, livelihoods, and policy interventions: Changing perspectives. *World Development*, 34(3):596–611.

Arrow, K., Bolin, B., Costanza, R., Dasgupta, P., Folke, C., Holling, C. S., Jansson, B.-O., Levin, S., Mäler, K.-G., Perrings, C., and Pimentel, D. (1995). Economic growth, carrying capacity, and the environment. *Science*, 268:520–521.

Baland, J.-M., Bardhan, P., Das, S., and Mookherjee, D. (2010a). Forests to the people: Decentralization and forest degradation in the Indian Himalayas. *World Development*, 38(11):1642 – 1656.

Baland, J.-M., Bardhan, P., Das, S., Mookherjee, D., and Sarkar, R. (2006). Managing the environmental consequences of growth: Forest degradation in the Indian Mid-Himalayas. *Indian Policy Forum*, 3(1):125–277.

Baland, J.-M., Bardhan, P., Das, S., Mookherjee, D., and Sarkar, R. (2010b). The environmental impact of poverty: Evidence from firewood collection in rural Nepal. *Economic Development and Cultural Change*, 59(1):23–61.

Baland, J.-M. and Bjorvatn, K. (2013). Conservation and employment creation: Can privatizing natural resources benefit traditional users? *Environment and Development Economics*, 18(03):309–325.

Baland, J.-M., Das, S., and Mookerjee, D. (2014). *Environment and Development Economics: Essays in Honour of Sir Partha Dasgupta*, chapter Forest Degradation in the Himalayas: Determinant and Policy Options, pages 202–240. Oxford University Press.

Baland, J.-M., Libois, F., and Mookherjee, D. (2015). Firewood collection in rural Nepal. Technical report, mimeo.

Baland, J.-M. and Platteau, J.-P. (1996). *Halting degradation of natural resources - Is there a role for rural communites*. Oxford: Oxford University Press.

Baltagi, B. H. and Li, D. (2002). Series estimation of partially linear panel data models with fixed effects. *Annals of Economics and Finance*, 3(1):103–116.

Barbier, E. B. (1997). Introduction to the environmental Kuznets curve special issue. *Environment and Development Economics*, 2(04):357–367.

Barbier, E. B. (1998). *The economics of environment and development: Selected essays*, chapter The concept of sustainable economic development and natural capital and the economics of environment and development. Edward Elgar.

Barbier, E. B. (2010). Poverty, development, and environment. *Environment and Development Economics*, 15:635–660.

Barbier, E. B., Sanchez, P., Thomas, R., and Wagner, A. (1997). The economic determinants of land degradation in developing countries [and discussion]. *Philosophical Transactions: Biological Sciences*, 352(1356):891–899.

Bellows, J. and Miguel, E. (2009). War and local collective action in Sierra Leone. *Journal of Public Economics*, 93(11-12):1144–1157.

Benabou, R. and Tirole, J. (2003). Intrinsic and extrinsic motivation. *Review of Economic Studies*, 70(3):489–520.

Besley, T. and Ghatak, M. (2001). Government versus private ownership of public goods. *The Quarterly Journal of Economics*, 116(4):1343–1372.

Besley, T. and Ghatak, M. (2005). Competition and incentives with motivated agents. *American Economic Review*, 95(3):616–636.

Bhattarai, B. (1996). 40 points demand. *South Asia Intelligence Review.*

Bilodeau, M. and Steinberg, R. (2006). *Donative nonprofit organizations*, volume 1 of *Handbook on the Economics of Giving, Reciprocity and Altruism*, chapter 19, pages 1271–1333. Elsevier.

Blattman, C. and Miguel, E. (2010). Civil war. *Journal of Economic Literature*, 48(1):3–57.

Bluffstone, R. A. (1995). The effect of labor market performance on deforestation in developing countries under open access: An example from rural Nepal. *Journal of Environmental Economics and Management*, 29(1):42–63.

Bohara, A. K., Mitchell, N. J., and Nepal, M. (2006). Opportunity, democracy, and the exchange of political violence: A subnational analysis of conflict in Nepal. *Journal of Conflict Resolution*, 50(1):108–128.

Brander, J. A. and Taylor, M. S. (1998). The simple economics of Easter Island: A Ricardo-Malthus model of renewable resource use. *American Economic Review*, 88(1):119–38.

Bundervoet, T., Verwimp, P., and Akresh, R. (2009). Health and civil war in rural Burundi. *Journal of Human Resources*, 44(2).

Cailmail, B. (2013). *Revolution in Nepal: An anthropological and historical approach to the People's War*, chapter The CPN (Masal) Bastion: A history of communist Militancy in Pyuthan district and its influence on the People's War, pages 141–163. Oxford University Press.

Carroll, M., DiMiceli, C., Sohlberg, R., and Townshend, J. (2000-2011). 250m MODIS Normalized Difference Vegetation Index. University of Maryland.

Castaneda, M. A., Garen, J., and Thornton, J. (2008). Competition, contractibility, and the market for donors to nonprofits. *Journal of Law, Economics, and Organization*, 24(1):215–246.

CBS (2004). Nepal Living Standards Survey II (2003/04): Survey design and implementation. Technical report, Nepal Central Bureau of Statistics.

CBS (2009). Nepal Living Standards Survey I (1995/96): Survey design and implementation. Technical report, Nepal Central Bureau of Statistics.

CBS (2011). Nepal Living Standards Survey Household 2010-2011. Statistical Report Vol. 1, Nepal Central Bureau of Statistics.

Chamarbagwala, R. and Moran, H. E. (2011). The human capital consequences of civil war: Evidence from Guatemala. *Journal of Development Economics*, 94(1):41 – 61.

Chaudhuri, S. and Pfaff, A. S. (2003). Fuel-choice and indoor air quality: a household-level perspective on economic growth and the environment. Technical report, Columbia University.

Chung, T.-Y. (1996). Rent-seeking contest when the prize increases with aggregate efforts. *Public Choice*, 87(1-2):55–66.

Conley, T. G. (1999). GMM estimation with cross sectional dependence. *Journal of Econometrics*, 92(1):1–45.

Cowan, S. (2013). *Revolution in Nepal: An anthropological and historical approach to the People's War.*, chapter Inside the People's Liberation Army: a military perspective, pages 301–332. Oxford University Press.

Dasgupta, P., Levine, S., and Lubchenco, J. (2000). Economic pathways to ecological sustainability. *Bioscience*, 50(4):339–345.

Dasgupta, P. and Mäler, K.-G. (1995). Poverty, institutions, and the environmental resource-base. In Behrman, J. and Srinivasan, T., editors, *Handbook of Development Economics*, volume 3, Part 1, chapter 39, pages 2371 – 2463. Elsevier.

Dayton-Johnson, J. and Bardhan, P. (2002). Inequality and conservation on the local commons: A theoretical exercise. *Economic Journal*, 112(481):577–602.

Dehon, C., Gassner, M., and Verardi, V. (2011). Extending the Hausman test to check for the presence of outliers. Working Papers ECARES ECARES 2011-036, ULB – Universite Libre de Bruxelles.

Démurger, S. and Fournier, M. (2011). Poverty and firewood consumption: A case study of rural households in northern China. *China Economic Review*, 22(4):512–523.

Diamond, J. (2005). *Collapse: How societies choose to fail or succeed*. Viking Press.

Do, Q.-T. and Iyer, L. (2010). Geography, poverty and conflict in Nepal. *Journal of Peace Research*, 47(6):735–748.

Duraiappah, A. K. (1998). Poverty and environmental degradation: A review and analysis of the nexus. *World Development*, 26(12):2169–2179.

Edmonds, E. V. (2002). Government-initiated community resource management and local resource extraction from Nepal's forests. *Journal of Development Economics*, 68(1):89–115.

Fetzer, T. (2014). Social insurance and conflict: evidence from India. Technical report, mimeo.

Foster, A. and Rosenzweig, M. (2003). Economic growth and the rise of forests. *Quarterly Journal of Economics*, 118(2):601–637.

Galdo, J. (2013). The long-run labor-market consequences of civil war: Evidence from the Shining Path in Peru. *Economic Development and Cultural Change*, 61(4):789 – 823.

Ghimire, P. (2013). *Revolution in Nepal: An anthropological and historical approach to the People's War.*, chapter The Maoists in Eastern Nepal: The example of Khotang, pages 114–138. Oxford University Press.

Glenn, E. P., Huete, A., Nagler, P. L., and Nelson, S. G. (2008). Relationship between remotely-sensed vegetation indices, canopy attributes and plant physiological processes: What vegetation indices can and cannot tell us about the landscape. *Sensors*, 8:2136–2160.

Gordon, H. S. (1954). The economic theory of a common property resource: The fishery. *Journal of Political Economy*, 62:124–142.

Grossman, G. M. and Krueger, A. B. (1995). Economic growth and the environment. *The Quarterly Journal of Economics*, 110(2):353–77.

Guidolin, M. and La Ferrara, E. (2007). Diamonds are forever, wars are not: Is conflict bad for private firms? *American Economic Review*, 97(5):1978–1993.

Gundimeda, H. and Kohlin, G. (2008). Fuel demand elasticities for energy and environmental policies: Indian sample survey evidence. *Energy Economics*, 30(2):517–546.

Hansmann, H. B. (1980). The role of nonprofit enterprise. *The Yale Law Journal*, 89:835–901.

Hardin, G. (1968). The tragedy of the commons. *Science*, 162:1243–1248.

Hatlebakk, M. (2007). LSMS data quality in Maoist influenced areas of Nepal. CMI Working Papers 6, CMI (Chr. Michelsen Institute), Bergen, Norway.

Hatlebakk, M. (2010). Maoist control and level of civil conflict in Nepal. *South Asia Economic Journal*, 11(1):99–110.

Heltberg, R., Arndt, T. C., and Sekhar, N. U. (2000). Fuelwood consumption and forest degradation: A household model for domestic energy substitution in rural India. *Land Economics*, 76(2):213–232.

Hsiang, S. M. (2010). Temperatures and cyclones strongly associated with economic production in the Caribbean and Central America. *Proceedings of the National Academy of Sciences*, 107(35):15367–15372.

Huang, L. and Smith, M. D. (2014). The dynamic efficiency costs of common-pool resource exploitation. *American Economic Review*, 104(12):4071–4103.

ICG (2005). Nepal's Maoists: Their aims, structure and strategy. Asia report 104, International Crisis Group.

INS, I. N. d. S. (1994). Annuaire de statistiques régionales. Technical report, Ministère des affaires économiques.

INSEC (2009). *Electronic data files*. Informal Service Service Center, Kathmandu.

INSEC (various years). *Human Rights Yearbook*. Informal Service Service Center.

ITTO (1994-2013). *Annual Review Statistics Database*. Internation Tropical Timber Organization.

ITTO (various years). *Annual Review and Assessment of the World Timber Situation*. Internation Tropical Timber Organization.

Jalal, K. (1993). *Sustainable development, environment and poverty nexus*. Asia Development Bank.

Kanel, K. R. (2008). *Promise, trust and evolution*, chapter So far so good: Next steps in Community forestry, pages 370–390. Oxford: Oxford University Press.

Kapaun, U. and Quaas, M. (2013). Does the optimal size of a fish stock increase with environmental uncertainties? *Environmental & Resource Economics*, 54(2):293–310.

Kondylis, F. (2010). Conflict displacement and labor market outcomes in post-war Bosnia and Herzegovina. *Journal of Development Economics*, 93(2):235–248.

Kosfeld, M. and Rustagi, D. (2015). Leader punishment and cooperation in groups: Experimental field evidence from commons management in ethiopia. *American Economic Review*, 105(2):747–83.

Kotchen, M. J. and Salant, S. W. (2011). A free lunch in the commons. *Journal of Environmental Economics and Management*, 61(3):245 – 253.

Kuan, J. (2001). The phantom profits of the opera: Nonprofit ownership in the arts as a make-buy decision. *Journal of Law, Economics and Organization*, 17:507–520.

La Mattina, G. (2014). Civil conflict, sex ratio and intimate partner violence in Rwanda. Technical report, Households in Conflict Network.

Lama Tamang, M. S., Gurung, S. M., Sornakar, D., and Magar, S. R. (2006). *Le maoisme au Népal: lecture d'une revolution*, chapter Changements sociaux dans les regions en conflit, pages 48–87. CNRS.

Lansley, J. (1996). Membership participation and ideology in large voluntary organisations: the case of the National Trust. *Voluntas*, 7:3:221–240.

Lawoti, M. (2010). *The Maoist insurgency in Nepal*, chapter Evolution and growth of the Maoist insurgency in Nepal, pages 3–30. Routledge.

Lecomte-Tilouine, M. (2013). *Revolution in Nepal: An anthropological and historical approach to the People's War.*, chapter Maoists despite themselves: Amid the People's war in a Maoist model village, Northern Gulmi, pages 212–257. Oxford University Press.

Lele, S. M. (1991). Sustainable development: A critical review. *World Development*, 19(6):607–621.

Lepart, J. and Marty, P. (2006). From natural reservations to the biodiversity territories: The case of france. *Annales de Géographie*, 651:485–507.

Levhari, D. and Mirman, L. J. (1980). The great fish war: An example using a dynamic Cournot-Nash solution. *Bell Journal of Economics*, 11(1):322–334.

LFP (2010). The resilience of community forestry user groups in conflict: Lessons from Nepal. Technical report, Livelihoods and Forestry Programme.

Libois, F. (2016). Households in times of war: Adaptation strategies during the Nepal civil war. Technical report, CRED, University of Namur.

Libois, F. and Verardi, V. (2013). Semiparametric fixed-effects estimator. *Stata Journal*, 13(2):329–336.

Lind, J. T., Moene, K. O., and Willumsen, F. (2014). Opium for the masses? conflict-induced narcotics production in Afghanistan. *The Review of Economics and Statistics*, 96(5):949–966.

Lopez, R. (1998). *1997 Annual World Bank Conference in Development Economics*, chapter Where Development Can or Cannot Go: The Role of Poverty-Environment Linkages. Washington D.C.

Macours, K. (2011). Increasing inequality and civil conflict in Nepal. *Oxford Economic Papers*, 63(1):1–26.

Maler, K. G. (1998). *1997 Annual World Bank Conference in Development Economics*, chapter Environment, Poverty and Economic Growth. Washington D.C.

Maronna, R. and Yohai, V. (2000). Robust regression with both continuous and categorical predictors. *Journal of Statistical Planning and Inference*, 89(1):197–214.

Mehta, A. K. and Lawoti, M. (2010). *The Maoist insurgency in Nepal*, chapter Military dimensions of the "People's War": insurgency and counter-insurgency in Nepal, pages 175–194. Routledge.

Menon, N. and Rodgers, Y. v. d. M. (2013). War and women's work: Evidence from the conflict in Nepal. *Journal of Conflict Resolution*, 59:51–73.

MENRIS-ICIMOD (2008). Ecology of Nepal.

Miguel, E. and Kremer, M. (2004). Worms: Identifying impacts on education and health in the presence of treatment externalities. *Econometrica*, 72(1):159–217.

Miguel, E. and Roland, G. (2011). The long-run impact of bombing Vietnam. *Journal of Development Economics*, 96:1–15.

Minoiu, C. and Shemyakina, O. (2012). Child health and conflict in Côte d'Ivoire. *American Economic Review*, 102(3):294–99.

Myneni, R., Hoffman, S., Knyazikhin, Y., Privette, J., Glassy, J., Tian, Y., Wang, Y., Song, X., Zhang, Y., Smith, G., Lotsch, A., Friedl, M., Morisette, J., Votava, P., Nemani, R., and Running, S. (2002). Global products of vegetation leaf area and fraction absorbed PAR from year one of MODIS data. *Remote Sensing of Environment*, 83(1-2):214–231. The Moderate Resolution Imaging Spectroradiometer (MODIS): a new generation of Land Surface Monitoring.

Nepal, M., Bohara, A. K., and Gawande, K. (2011). More inequality, more killings: The Maoist insurgency in Nepal. *American Journal of Political Science*, 55(4):886–906.

Nepal, M., Nepal, A., and Grimsurd, K. Unbelievable but true: Improved cookstoves are not helpful in reducing firewood demand in Nepal. Working papers 51, The South Asian Network for Development and Environmental Economics.

Newson, R. (2000). BSPLINE: Stata modules to compute B-splines parameterized by their values at reference points. Statistical Software Components, Boston College Department of Economics.

Newson, R. (2001). B-splines and splines parameterized by their values at reference points on the x-axis. *Stata Technical Bulletin*, 10(57).

Noussair, C. N., van Soest, D., and Stoop, J. (2015). Cooperation in a dynamic fishing game: A framed field experiment. *American Economic Review*, 105(5):408–13.

Oli, B. N. and Shrestha, K. (2009). Carbon status in forest of Nepal: An overview. *Journal of Forest and Livelihood*, 8:63–67.

Onesto, L. (2005). *Dispatches from the People's War in Nepal*. Pluto Press.

Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action*. Cambridge: Cambridge University Press.

Pivovarova, M. and Swee, E. L. (2015). Quantifying the microeconomic effects of war using panel data: Evidence from Nepal. *World Development*, 66(C):308–321.

Rose-Ackerman, S. (1982). Charitable giving and "excessive" fundraising. *The Quarterly Journal of Economics*, 97(2):193–212.

Royston, P. and Sauerbrei, W. (2007). Multivariable modeling with cubic regression splines: A principled approach. *Stata Journal*, 7(1):45–70(26).

Salamon, L. M. (2010). Putting the civil society sector on the economic map of the world. *Annals of Public and Cooperative Economics*, 81(2):167–210.

Samuelson, P. A. (1954). The transfer problem and transport costs, ii: Analysis of effects of trade impediments. *The Economic Journal*, 64(254):pp. 264–289.

Sekeris, P. G. (2014). The tragedy of the commons in a violent world. *The RAND Journal of Economics*, 45(3):521–532.

Sethi, R. and Somanathan, E. (1996). The evolution of social norms in common property resource use. *American Economic Review*, 86(4):766–88.

Sethi, R. and Somanathan, E. (2006). A simple model of collective action. *Economic Development and Cultural Change*, 54(3):725–47.

Sharma, K. (2006). The political economy of civil war in Nepal. *World Development*, 34(7):1237–1253.

Shemyakina, O. (2011). The effect of armed conflict on accumulation of schooling: Results from Tajikistan. *Journal of Development Economics*, 95(2):186–200.

Shrestha-Schipper, S. (2013). *Revolution in Nepal: An anthropological and historical approach to the People's War.*, chapter The political context and the influence of the People's War in Jumla, pages 258–297. Oxford University Press.

Shyamsundar, P. and Ghate, R. (2011). Rights, responsibilities and resources: Examining community forestry in South Asia. Working papers 59, The South Asian Network for Development and Environmental Economics.

Solano, R., Didan, K., Jacobson, A., and Huete, A. (2010). MODIS Vegetation Index user's guide: MOD13 Series. Technical report, The University of Arizona.

Somanathan, E., Prabhakar, R., and Mehta, B. S. (2009). Decentralization for cost-effective conservation. *Proceedings of the National Academy of Sciences of the United States of America*, 106(11):4143–4147.

Thapa, D. (2004). *A Kingdom under Siege: Nepal's Maoist insurgency, 1996 to 2004*. Zed books.

Tirole, J. and Bénabou, R. (2006). Incentives and prosocial behavior. *American Economic Review*, 96(5):1652–1678.

Ujpreti, B. R. (2010). *External engagement in Nepal's armed conflict*, chapter Military dimensions of the "People's War": insurgency and counter-insurgency in Nepal, page 219. Routledge.

UNEP (2011). Forest management in Nepal. http://www.unep.org/ greeneconomy/ SuccessStories/ ForestManagementinNepal/ tabid/29869/Default.aspx. Accessed: 2015-08-27.

Valente, C. (2011). What did the maoists ever do for us? education and marriage of women exposed to civil conflict in Nepal. Working Papers 2011009, The University of Sheffield, Department of Economics.

Valente, C. (2014). Education and civil conflict in Nepal. *The World Bank Economic Review*, 28(2):354–383.

Valente, C. (2015). Civil conflict, gender-specific fetal loss, and selection: A new test of the Trivers-Willard hypothesis. *Journal of Health Economics*, 39:31 – 50.

Verardi, V. and Croux, C. (2009). Robust regression in Stata. *Stata Journal*, 9(3):439–453.

Verpoorten, M. (2009). Household coping in war- and peacetime: Cattle sales in Rwanda, 1991-2001. *Journal of Development Economics*, 88(1):67–86.

Word Bank (2000). *India: alleviating poverty through forest development.*

Yandle, B., Vijayaraghavan, M., and Bhattarai, M. (2002). *The environment Kuznets Curve: a primer*. Political Economy Research Center, Center for Free Market Environmentalism, Montana.